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Waste Minimization Audit Report
Case Studies of Minimization of
Cyanide Waste from Electroplating Operations

Jacobs Engineering Group, Inc., Pasadena, CA

Prepared for

Environmental Protection Agency, Cincinnati, OH

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WASTE MINIMIZATION AUDIT REPORT

CASE STUDIES OF MINIMIZATION OF CYANIDE WASTE FROM ELECTROPLATING OPERATIONS

by

Jacobs Engineering Group Inc.
Hazardous and Toxic Materials Division
Pasadena, California

Contract No.: 68-01-7053, WA #46

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To promote waste minimization activities in accordance with the national policy objectives established under the 1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act of 1976 (RCRA), the Hazardous Waste Engineering Research Laboratory (HWERL) of the USEPA Office of Research and Development has undertaken a project to develop and test a waste minimization (WM) audit procedure.

As part of this project, a total of 6 WM audits were carried out in four separate facilities. This report presents the results of the on-site WM audits performed at two electroplating facilities that generate cyanide-bearing wastes. The report also describes the WM audit procedure as it has developed from the initial (pre-project) sequence of steps, to the modified (post-project) sequence that reflects the experience gained during this HWERL project.

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid and hazardous wastes. These materials, if improperly dealt with, can threaten both public health and the environment. Abandoned waste sites and accidental releases of toxic and hazardous substances to the environment also have important environmental and public health implications. The Hazardous Waste Engineering Research Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs and regulations of the Environmental Protection Agency, the permitting and other responsibilities of State and local governments and the needs of both large and small businesses in handling their wastes responsibly and economically.

This report describes several studies carried out to identify waste minimization opportunities for hazardous waste reduction. It will be useful to individuals interested in hazardous waste minimization technology and technologies.

For further information, please contact the Alternative Technologies Division of the Hazardous Waste Engineering Research Laboratory.

Thomas R. Hauser
Director
Hazardous Waste Engineering Research Laboratory

ABSTRACT

To promote waste minimization activities in accordance with the national policy objectives established under the 1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act of 1976 (RCRA), the Hazardous Waste Engineering Research Laboratory (HWERL) of the USEPA Office of Research and Development has undertaken a project to develop and test a waste minimization (WM) audit procedure.

As part of this project, a total of 6 WM audits were carried out in four separate facilities. This report presents the results of the on-site WM audits performed at two electroplating facilities that generate cyanide-bearing wastes. The report also describes the WM audit procedure as it has developed from the initial (pre-project) sequence of steps, to the modified (post-project) sequence that reflects the experience gained during this HWERL project.

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1. INTRODUCTION

1.1 Background and Report Organization

The national policy objectives established under the 1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act of 1976 include the goal of reduction or elimination of hazardous waste as expeditiously as possible. To promote these activities, the Hazardous Waste Engineering Research Laboratory (HWERL) of the U.S. EPA, Office of Research & Development has undertaken a project to develop and test a waste minimization audit procedure. It is envisioned that such a procedure would be useful to the generators of hazardous waste in their search for waste minimization alternatives.

The potential value and desirability of conducting waste audits has been recognized by a number of authors, although different approaches and scope limits have been suggested for audit activities (Fromm and Callahan 1986, Kahane 1986, Pojasek 1986, U.S. Congress 1986, USEPA 1986a). In this HWERL project, a recently developed audit procedure was tested by conducting actual audits in cooperating industrial and government facilities. A total of 6 audits were carried out in 4 different facilities. This initially proposed audit procedure was then modified to reflect insights and experience gained in the field.

Section 2 of this report describes the elements of an overall waste minimization program, of which the audit procedure is an important component. Section 3 deals with the waste minimization audit procedure itself, its development, and its final recommended form. Sections 4 and 5 present the results of the waste audits performed at two separate facilities with electroplating operations which generate cyanide-bearing waste. The 4 other audits performed as part of this project are discussed in separate reports.

2. WASTE MINIMIZATION PROGRAM

2.1 Comparable Program Types

Structured programs designed to improve the cost, energy efficiency, environmental, safety, or other aspects of an industrial undertaking are not a new concept. During

World War II, the General Electric Corporation developed standardized procurement procedures for reducing product cost without sacrificing functionality. Later, similar procedures were developed and applied to reduce the costs of design and construction projects. This activity, known as value management, value engineering, or value analysis, is currently well established as a government requirement. In fact, it was mandated by the U.S. EPA for construction projects involving waste water treatment plants; a subsequent study of 56 treatment plants showed that these cost reduction programs saved $95 million, for a 12 to 1 return on investment (Zimmerman and Hart 1982).

Environmental compliance audits and reviews are also becoming well established and are acquiring the status of the industry norm. The primary objective of environmental audits is to "..determine the status of corporation's compliance with federal, state and local environmental laws and regulations" (Truitt et al. 1983). Additionally, such audits can often provide information for risk assessment and corporate planning.

Energy conservation audits are performed to reduce energy consumption per unit of production. It was estimated that energy audits helped save chemical process industries about $1 billion between 1974 and 1979 (Parkinson 1979). Other related structured programs include safety reviews, hazard analyses, or failure mode and effects analyses (Williams 1976). Waste minimization programs can be considered to be in the same category of programs.

The principal objective of a waste minimization (WM) program is to reduce the quantity and/or toxicity of waste effluents leaving the production process in a manner consistent with the goals of protecting human health and environment. Unlike environmental audit programs, a WM program does not seek to determine or improve the regulatory compliance status of a facility. Rather, it is primarily oriented toward producing a set of effective measures to reduce waste generation.

2.2 Waste Minimization Program Organization

Table 2-1 presents a breakdown of WM program elements. In the context of an overall WM program, the waste auditing process (composed of pre-audit, audit, and post-audit phases) follows the program initiation/planning phase. During the initiation/planning phase, the commitment of top management to reduce waste generation must be first

TABLE 2-1 WASTE MINIMIZATION (WM) PROGRAM ELEMENTS

Program Phase	Job Plan* Phase	Elements
I. Initiation/Planning		o Secure commitment/authority o Establish goals o Establish organization
II. Pre-audit	Information	o Preparation for the audit o Pre-audit inspection o Data compilation and waste stream selection
III. Audit	Creative	o Facility inspection o Generate comprehensive set of WM options
	Judgement	o Options evaluation o Selection of options for feasibility analysis
IV. Post-Audit	Development	o Technical and economic feasibility analysis
	Recommendation	o Report preparation
V. Implementation		o Selection of options for implementation o Design, procurement, and construction o Startup o Performance monitoring

*term adopted from value management program.

established. This is often done with a formal directive signed by the chief executive officer of the firm or the administrator of a government organization (League of Women Voters 1985). The organizational commitment to start a WM program is often associated with a goal setting process (e.g., DuPont is considering an annual 5% waste reduction goal).

A corporate WM program may be organized in a typical pyramid structure, with command and monitoring functions centered at the corporate level, and implementation responsibility totally delegated to individual plants. A corporate-level independent expert task force may be formed to assist individual plants with setting up and executing their own WM programs.

At the individual plant level, the WM program can follow the scheme successfully used at Union Carbide for energy conservation efforts. At Union Carbide plants, a plant program coordinator is appointed and supported by a committee. The coordinator then selects and oversees individuals in each department who are responsible for devising and/or carrying out WM activities in their respective departments (Williams 1976).

The program planning phase should include selection of audit team(s) to carry out the next program phase. The audit team leader should have a strong technical background, demonstrated problem solving ability, and preferably, experience associated with the relevant process(es). Additionally, the leader should possess strong management and communication skills. It is preferable that the leader, or at least some members of the audit team, not have a strong previous association with the plant, so as to bring a fresh, independent, and unbiased perspective to the audit process. Such outsiders can be independent consultants or qualified personnel from other plants.

The audit team must have access to all required documentation and to a wide variety of plant personnel. During a recent internal workshop on waste minimization conducted by a major U.S. corporation, the participants (mostly environmental affairs managers at individual plants) were asked who should provide support to a waste audit team. The following responses were obtained:

- Raw material suppliers
- QA/QC department
- Outside consultants

- o Customer representatives
- o Process engineer
- o Safety engineer
- o Materials engineer
- o Foreman
- o Plant manager and
- o Purchasing

In short, the organization should be prepared to provide the audit team with access to a wide range of people inside and outside of the firm. The teams employed in carrying out the two pilot audits described in this report were comprised entirely of employees of outside consulting/engineering firms. The composition of the outside audit teams and of the support groups on the facility side is presented in Table 2-2.

The waste auditing process (WM program phases II, III and IV), described in detail in the next section, provides the key input to the implementation phase of the program, i.e., recommendations on which WM measures are to be implemented. Once a decision to proceed with implementation of a specific WM measure is made, subsequent activities follow a well established, conventional pattern. Detailed design follows preliminary design; the procurement effort proceeds through inquiry and definitive bids, bid analysis, and expediting stages; and the construction effort proceeds along the path determined by a detailed schedule and budget. The budget is controlled through estimates of project cost performed at various project stages with an ever increasing accuracy as material and labor requirements become better defined. Startup follows mechanical completion. The final element of the implementation phase is the ongoing performance monitoring conducted in order to ascertain the waste reduction effectiveness of the changes made.

3. WASTE AUDITING

3.1 Waste Minimization (WM) Audit Procedure

As shown in Table 2-1, waste audits are a central part of a WM program. The auditing process is subdivided into pre-audit, audit, and post-audit phases. The recommended sequence of steps shown in Table 2-1 (also shown in expanded form in Table 3-1), is based on modifications of the originally proposed sequence which is presented in

TABLE 2-2 WASTE AUDIT TEAMS AND RESIDENT SUPPORT GROUPS FOR THE TWO PILOT AUDITS AT CYANIDE WASTE GENERATING FACILITIES

Facility C-1 (air base)

A. Outside Audit Team

Chemical engineer[1], B.S., 28 yrs experience
Chemical engineer, M.S., 2 yrs experience
Independent consultant[2], PhD, environmental engineering, 22 yrs experience
Independent consultant[2], B.S., chemistry, 30 yrs experience

B. Resident Support Team

Environmental coordinator
Environmental engineer
Electroplating facility engineering supervisor
Metallurgist
Chemist (materials science group)

Facility C-2 (small electroplating shop)

A. Outside Audit Team

Environmental engineer[1], PhD, 12 yrs experience
Chemical engineer, M.S., 2 yrs experience
Chemical engineer, B.S., 6 yrs experience
Independent consultant[2], B.S. chemistry, 30 yrs experience

B. Resident Support Team

Owner
Operators

---

1. Audit team leader.
2. Technical support and review function only.

TABLE 3-1 RECOMMENDED WASTE MINIMIZATION AUDIT PROCEDURE

Program Phase	Activities	Product
Pre-Audit	1. Preparation for the audit	o needs list/inspection agenda
	2. Pre-audit meeting and inspection	o notes
	3. Data compilation and waste stream selection	o facility and process description
		o waste description
		o rationale for selection
Audit	4. Facility inspection	o notes
	5. Generation of a comprehensive set of WM options	o list of proposed options with written rationale
	6. Options evaluation	o independent options ratings by audit team and by plant personnel followed by joint review
	7. Selection of options for feasibility analyses	o list of selected options
		o options interim report
Post-Audit	8. Technical and economic feasibility analysis	o study or budget grade estimates of capital and operating costs; profitability analysis
	9. Final report preparation	o final report with recommendations

Table 3-2. Modifications were made to reflect the experience and insights gained as a result of actual audit work. Sections below detail each of the nine steps of the recommended audit procedure shown in Table 3-1.

3.1.1 Preparation for the Audit

The objective of this activity is to gain background information about the facility to be audited. Preparation should include examination of references related to the activities performed at the facility, and if available, review of process flow diagrams, heat and material balances, piping and instrumentation diagrams, and all documentation regarding equipment cleaning and waste handling procedures. The result of proper preparation should be a well-defined needs list, inspection agenda, or a checklist detailing what is to be accomplished, what questions or issues need to be resolved, and what information needs to be gathered.

For one of the two host facilities audited in this report, the needs list (Table 3-3) was provided to the resident support team in advance of the site visit. This improved the efficiency of the site visit since it allowed the facility personnel to assemble the materials needed by the audit team in advance. A more generalized list of documents and information sources is given in Table 3-4.

3.1.2 Pre-Audit Meeting

The purpose of this meeting is to become familiar with plant operations and with plant personnel. Initial contacts with plant personnel should include solicitation of their views on the focus and function of the audit. This will help to identify areas of concern to the facility. The information needs defined in the previous step would be discussed here and hopefully fulfilled. A guided tour of the facility should be taken.

At this initial visit, the groundwork for a successful working relationship with facility personnel must be laid. The importance of a cooperative attitude and active involvement by host facility personnel to the success of the audit process must be stressed. The initial point of contact at the facility (Plant Manager, Environmental Coordinator, etc.) must be enlisted as a "Product Champion" for the program before the audit commences. He/she must be encouraged to relay the message of cooperation and involvement to others at the facility.

TABLE 3-2 INITIALLY PROPOSED WASTE MINIMIZATION AUDIT PROCEDURE

Job Plan Element	Step	
Information phase	1.	Preparation for inspection
	2.	Facility inspection
	3.	Process and waste stream description
Creative phase	4.	Generation of WM options
Judgement phase	5.	Preliminary evaluation and ranking of options
	6.	Presentation, discussion and joint review of options with plant personnel
	7.	Selection of options for feasibility analysis
Development phase	8.	Technical and economic feasibility analysis
Recommendation phase	9.	Final report preparation

TABLE 3-3 WASTE MINIMIZATION AUDITS - INFORMATION NEEDS LIST FOR CYANIDE STREAMS AT FACILITY C-1

1. Process Flow Diagrams (PFD's) with Heat and Material Balances (HMB's).
2. Piping and Instrumentation Diagrams (P&ID's).
3. Plot Plan or general arrangement of equipment.
4. Process description (work flow, solution flow, liquid and solid wastes).
5. Composition of baths and makeup water.
6. Quantities and costs of chemicals.
7. Dimensions and operating gallonage of all tanks.
8. Quantities and costs of disposal for all wastes, liquid and solid; frequency of bath replacement.
9. Materials of construction.
10. History of previous waste management projects, and any related documentation.

TABLE 3-4 WASTE MINIMIZATION AUDITS
GENERALIZED LIST OF INFORMATION SOURCES

- Design process flow diagrams (PFD) with heat and material balances (HMB) for process and pollution control systems
- Equipment list
- Piping and instrument diagrams (P&ID)
- Materials application diagrams (MAD)
- Plot and elevation plans
- General arrangement drawings
- Piping layout drawings
- Operation manuals, process descriptions
- Permits and/or permit applications
- Emission inventories
- Hazardous waste manifests
- Annual (or biennial) reports
- Waste assays
- Operator data logs, batch sheets
- Materials purchase orders
- Environmental audit/review reports
- Production schedules
- Organization chart

3.1.3 Data Compilation and Waste Stream Selection

At this point, it is recommended that a written description of the facility, process or operation, and of waste streams be developed, based on the completed data. The description should encompass:

- o Facility location and size;
- o Description of operations or process(es) of concern, including diagrams necessary to detail the pertinent aspects of waste generation; and
- o Waste stream(s) description centering on sources and current methods of management. This information should be supplemented with summaries of generation rates, compositions, and raw material and disposal costs.

Descriptions of facility, process, and waste stream(s) for the two pilot audit facilities are given in Sections 4 and 5. Such descriptions summarize, in essence, all the pertinent information acquired.

If the waste streams were not selected during the pre-audit meeting or the initial inspection, then selection must be made at this point. Selection should be based on discussions with plant personnel and on the independent assessment of the project team. The criteria used for selection must include at a minimum:

- Waste composition
- Quantities of waste generated
- Degree of hazard (toxicity, flammability, corrosivity)
- Method and cost of disposal
- Potential for minimization and recycle
- Regulatory issues (e.g., compliance status or problems)

For the two case studies dealing with cyanide wastes, stream selection was not a required step. Focusing of the audits on a particular type of waste (cyanides) simplified the selection process, since the only cyanide waste producing operation performed at the audited facilities was electroplating. For the audit reports dealing with solvent waste (discussed in a companion report), selection could not be performed until after the site visits. This was due to the diverse nature of the operations and sources that generate solvent waste.

3.1.4 Audit Inspection

In the course of pre-audit phase activities, a general understanding of the process facility operations and, most importantly, of waste sources will have been established. Also, the waste stream selection process will have been finalized and the information summarized in a written description of the facility, process, and waste stream(s).

With the needed understanding of the process and the project focus in place, the audit inspection can now be conducted. Typically, the inspection would focus on the select aspects of the operation identified through the pre-audit activities. The governing objective is to evolve a fuller understanding of principal and secondary causes of waste generation and to cover the items missed in the pre-audit stage.

The audit inspection is the ultimate step in the information gathering process. The following guidelines have been formulated as a result of the work performed in this project:

1. Have an agenda ready--this should cover all points that still require clarification following the pre-audit work.

2. Schedule the inspection to coincide with the particular operation that is of interest, e.g., make-up chemical addition, bath sampling, bath replacement, etc.

3. Obtain permission to interview the operators, shift supervisors, and foremen directly. Listen attentively and do not hesitate to question more than one person if the answer is not forthcoming. Try to assess the operators' and their supervisors' awareness of waste generation aspects of the operation. Note their familiarity (or the lack thereof) with the impacts their operation may have on other operations, e.g., the effect of routing spent stripping solutions into the existing waste water treatment plant.

4. Obtain permission to photograph the facility. Photographs are especially valuable in the absence of plan layout drawings. Many details can be captured in photographs that otherwise could be forgotten or inaccurately recalled at a later date.

5. Observe the "housekeeping" aspect of the operation. Check for signs of spills or leaks. Ask to visit the maintenance shop and inquire about their problems in maintaining the equipment leak-free. Assess the overall cleanliness and order of the site.

6. Assess the level of coordination of environmental activities between various departments.

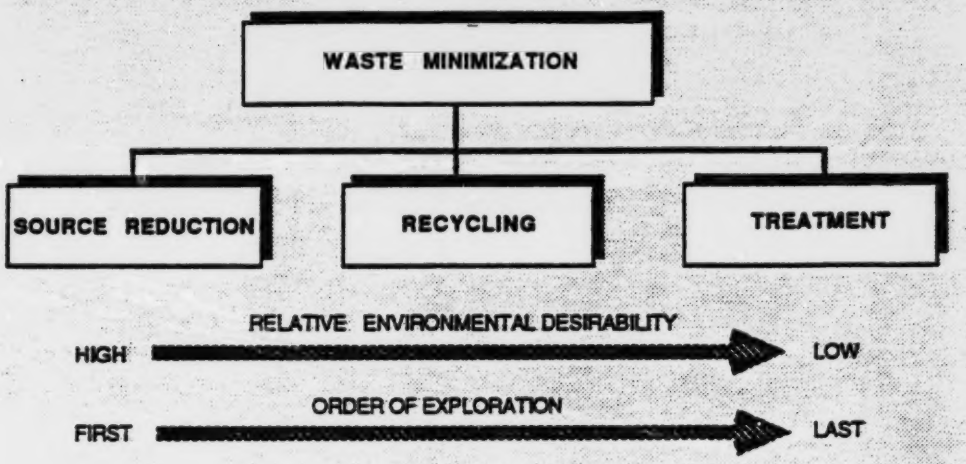
It is of benefit during the planning and conduction of the audit inspection itself to mentally "walk the line" from the suspected source of waste generation to the point of exit, be it a treatment unit, storage facility, or haulage to off-site TSD facilities. The audit inspection must result in a clear understanding of waste generation causes.

3.1.5 Generation of WM Options

Up until this point, the audit process has been mainly oriented toward information gathering and organization. These activities should have established a thorough understanding of the origins of waste generation and of the process or facility operations in general. The audit activity is now ready to move into the creative phase.

The objective of this step is to generate a comprehensive set of WM options. This may take the form of a "brainstorming" session involving audit team members or through separate efforts by individual members. A combination of these approaches was found to be of value during the pilot audits. In this stage of the audit process, it is important to generate as large a number of options as possible. The WM measures currently in place in the audited facility should also be listed. This knowledge often leads to formulation of additional options and provides valuable insight for the subsequent option evaluation step.

Options generation should generally follow a hierarchy in which most of the effort would focus on source reduction, followed by recycling, followed by treatment. Such a hierarchy of effort stems from the environmental desirability of source reduction over recycling, and of recycling over treatment. Current EPA-proposed definitions of waste minimization and of key waste minimization terms are given in Figure 3-1. A generalized guide to various source reduction elements is given in Figure 3-2. For discussion of the terms and examples illustrating each element, the reader is referred



WASTE MINIMIZATION

The reduction to the extent feasible of hazardous waste that is generated or subsequently treated, stored or disposed of. It includes any source reduction or recycling activity undertaken by a generator that results in either (1) the reduction of total volume or quantity of hazardous waste or (2) the reduction of toxicity of the hazardous waste, or both, so long as such reduction is consistent with the goal of minimizing present and future threats to human health and environment (EPA's Report to Congress, 1986).

SOURCE REDUCTION

The reduction or elimination of waste generation at the source, usually within a process (op.cit).

RECYCLING

A material is "recycled" if it is used, reused, or reclaimed (40 CFR 261.1 (c) (7)). A material is "used or reused" if it is either (1) employed as an ingredient (including its use as an intermediate) to make a product; however a material will not satisfy this condition if distinct components of the material are recovered as separate end products (as when metals are recovered from metal containing secondary materials) or (2) employed in a particular function as an effective substitute for a commercial product (40 CFR 261.1 (c) (5)). A material is "reclaimed" if it is processed to recover a useful product or if it is regenerated. Examples of recovery of lead values from spent batteries and regeneration of spent solvents (40 CFR 261.1 (c) (4)).

TREATMENT

Any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste or so as to render such waste non-hazardous, safer for transport, amenable for recovery, amenable for storage or reduced in volume. Such term includes any activity or processing designed to change the physical form or chemical composition of hazardous waste so as to render it non-hazardous (RCRA, Subtitle A, Section 1004(34), PL-98-616).

Figure 3-1 Components of waste minimization, their hierarchy and definitions.

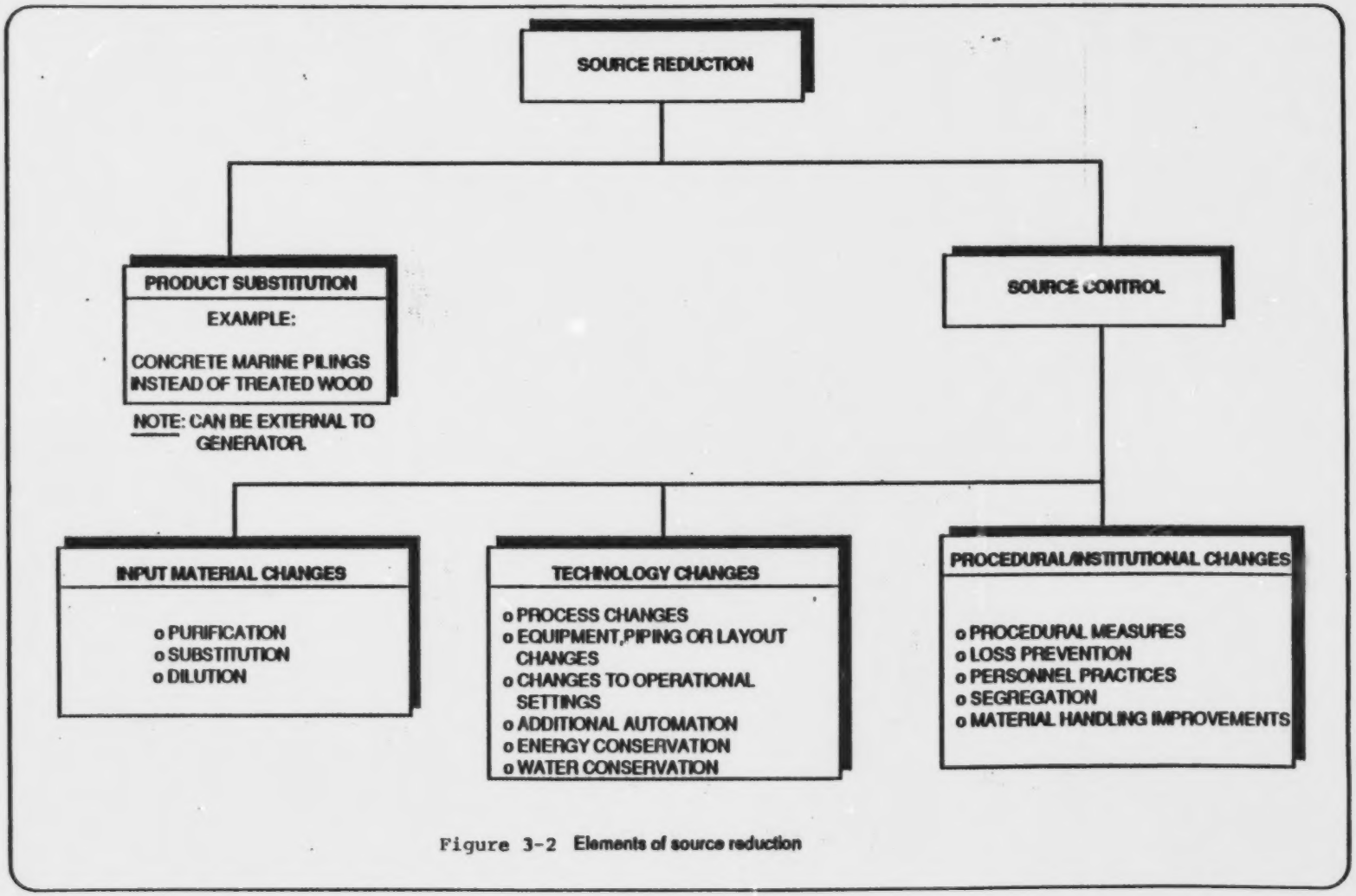


Figure 3-2 Elements of source reduction

to the EPA support document for the 1986 Report to Congress on Waste Minimization (USEPA 1986b).

To generate options, it is often necessary to examine the technical literature. The reference section of this report provides the listing of sources consulted for cyanide waste reduction. Options can also be formulated through discussion with manufacturers of equipment or suppliers of process input materials. A third way to generate options is through the use of a checklist. A checklist suitable for electroplating wastes was formulated, based upon the audit work performed at the two facilitites and is presented in Table 3-5.

The result of the WM options generation step should be a report in which each option is identified, together with a brief description of the rationale for its inclusion. Included should be such items as effectiveness, applicability, operating constraints, and any other information regarding the potential success or failure of the option. For examples of these reports, refer to Sections 4.6 and 5.6

3.1.6 Options Evaluation

Each of the options postulated in the preceeding step must undergo a preliminary (mostly qualitative) evaluation. The objective of this evaluation is to weed out the measures that do not merit additional consideration and to rank the remaining measures in the order of their overall desirability.

It is recommended that the evaluation process be performed by two independent groups or individuals, e.g. by the audit team and by the host facility personnel. Getting and keeping the facility personnel actively involved in the evaluation process is an important tool in maintaining their interest in the overall waste minimization process.

The evaluation should include, at a minimum, consideration of the following aspects:

- Waste reduction effectiveness (i.e., reduction of waste quantity and/or toxicity)
- Extent of current use in the facility
- Industrial precedent

TABLE 3-6 SOURCE REDUCTION OPTIONS CHECKLIST FOR CYANIDE WASTES FROM ELECTROPLATING OPERATIONS

OPTIONS	COMMENTS
Drag-out minimization	- By reducing drag-out, less of the plating solution leaves the tank.
Workpiece positioning	- Proper positioning of the part on the rack reduces solution drag-out.
Withdrawal speed and drainage	- Slow speeds reduce drag-out. Parts should be allowed to drain over tank.
Drag-out recovery	- Drain boards and drip tanks can be used to recover plating solutions.
Concentration	- Reducing the concentration of the bath reduces losses due to drag-out.
Temperature	- Increased temperature reduces solution viscosity / surface tension.
Surfactants	- Lower the surface tension of the solution which reduces drag-out.
Extension of bath life	- Reduces the frequency of spent bath replacement.
Drag-in reduction	- Efficient rinsing prevents cross-contamination of solutions.
Deionized water	- Reduces the build-up of calcium and magnesium ions in the bath.
Impurity removal	- Can be performed by chemical precipitation, freezing (carbonates), or by filtering (particulates).
Rack maintenance	- Corrosion and salt deposits on the rack can contaminate plating baths.
Anodes	- Use of purer anodes and bags will prevent insoluble impurities in the anodes from entering the bath. Anodes should be removed when not in use.
Return solution	Some manufacturers of plating solutions will reprocess spent baths.
Minimization of rinse water	- Reducing flow promotes recovery of metals and makes treatment more effective.
Automatic flow control	- Reduces water use while insuring required degree of rinsing.
Agitation	- Increases rinsing efficiency which reduces the volume of water needed.
Multiple tanks	- Counter-current rinsing can reduce water requirements by 60 to 90 percent.
Spray/fog nozzles	- More efficient than rinsing a part in a tank of water.
Closed-loop rinsing	- Susceptable to impurity build-up and may require the use of a recovery system, e.g., evaporation, ion exchange, reverse osmosis, electrodialysis.
Non-cyanide solutions	- Eliminates the generation of a cyanide-bearing waste.
Copper plating	- Pyrophosphate copper plating solution may be used as a replacement.
Cadmium plating	- Substitutes include cadmium fluoborate and acid sulfate cadmium baths.
Silver stripping	- May be performed with potassium nitrate and ammonium hydroxide.
Alternate plating techniques	- Eliminates the use of hazardous plating solutions.
Ion vapor deposition	- Can be used to plate parts with cadmium or aluminum. Required equipment is very complex and expensive.
Good operating practices	- Helps to minimize waste generation through procedural policies.
Segregation	- Proper segregation can prevent mixing of hazardous and non-hazardous waste.
Training/supervision	- Operator awareness can help identify and eliminate wasteful practices.
Spill and leak prevention	- Reduces the loss of materials and the generation of clean-up wastes.
Maintenance	- Preventive and corrective maintenance reduces spills, leaks, and upsets.
Material tracking/control	- Provides the facility with accurate material balances which can be used to identify and quantify material and waste handling problems.

- o Technical soundness
- o Cost
- o Effect on product quality
- o Effect on plant operations
- o Implementation period and
- o Resources availability and requirement.

The reviewers should discuss each proposed measure one by one in each area given above. After discussion, each measure would be rated qualitatively on scale of 0 (low) to 10 (high) in terms of:

- o Waste reduction effectiveness
- o Extent of current use in the facility and
- o Future application potential (a qualitative measure of probability that the option will be implemented, and which is dependent on the last 7 of the 9 elements listed above).

The rating system is in essence an activity management tool for the evaluation process. It forces the participants to follow a defined pattern of steps and provides a framework for resolving differences of opinions. The product of the evaluation process is the orderly listing of each measure, along with the associated rating in each of the three categories. The reader is referred to Tables 4-3 and 5-4 for examples.

3.1.7 Selection Options for Feasibility Analysis

Following the evaluation (i.e., rating each option for its waste reduction effectiveness, extent of current use in the facility, and future application potential) by two independent groups or individuals, the ratings are compared and discussed in a joint meeting. The objective of this meeting is to develop ratings which are mutually acceptable. While the ratings obtained by the two independent teams will differ, the differences are likely to be small for the most part. Major differences that signify vastly different perceptions must be reconciled during this meeting.

The product of the meeting is a WM options list with revised ratings. The final ratings are then used to calculate two values called the Current Reduction Index (CRI) and the Future Reduction Index (FRI):

CRI = score for effectiveness X score for extent of current use/10

FRI = score for effectiveness X (10 - score for extent of current use) X score for future application potential/100

The CRI is a qualitative measure of the amount of waste already reduced by the facility due to a given technique. The FRI is a qualitative measure of the amount of waste that can be reduced by implementing a given technique or option.

Selection of options for additional feasibility evaluation is based on the FRI value. The higher the value, the more attractive the option as a candidate for additional consideration. Also to be considered for selection are measures that have a low FRI value simply because the extent of their current use is high. Such measures might be considered for additional implementation since their usefulness has been proven. However, their effect on additional waste volume or toxicity reduction is probably relatively low.

The number of measures promoted to the feasibility evaluation stage depends on the time, budget, and resources available for such study.

3.1.8 Analysis of Technical and Economic Feasibility

The specific WM options selected in the previous step must be analyzed to determine the equipment and materials that would be required. A preliminary process flow diagram, heat and material balance, and equipment list is developed. Equipment is sized and budget quotes with preliminary vendor information obtained. In cases involving a large number of equipment items and substantial amounts of piping and instrumentation, factored estimation techniques can be used.

In retrofit cases, it may be enough to prepare sketches of the proposed equipment installation (e.g. drain boards or manifold for spray rinsing) in order to obtain sufficient resolution of detail needed for a budget-grade estimate. The complexity of the preliminary engineering work required may vary considerably. It would probably be worthwhile to allow prospective vendors to inspect the site (although it has not been done in any of the audits performed for this project). Calculations have to be made to ascertain the viability of proposed option(s). For example, a decrease of

drag-out using drain boards had to be evaluated in terms of the effect of a decreased purge rate on the solution's longevity (see Section 4). This above effort yields a summary of capital and operating costs for the option. The estimates are typically of study-grade (±30%) accuracy.

Following development of capital and operating costs for each option, the analysis is focused on an estimation of profitability. For this project, a simple payback period method was used, considering the rather moderate levels of capital investment involved and the lack of "borderline" cases. More sophisticated methods (net present value or internal rate of return) would be used for more capital-intensive cases. Additional information on the estimation of profitability of WM measures can be found in a recent publication by Fromm and Butler (1986).

3.2 Observations Made During The Audits

Some of the most important lessons learned in the pilot audits relate to the human element of the audit process, i.e., to the interaction between the audit team and host facility personnel. It obviously is important that host facility personnel become and remain active participants throughout the audit process. Some non-technical skills of the audit team personnel, and particularly of the audit team leader were found to be extremely important here.

The audit team leader must be an effective and aggressive communicator, as well as a technical expert, because the team leader must play an important role as a facilitator for the audit team and host facility personnel alike. In one case, a reserved and low key attitude and behavioral style by the audit team initially led to a passive and relatively disengaged stance by the host facility personnel.

3.2.1 Pre-Audit Phase

For both audits, the availability of the required process documentation was not satisfactory. Flow diagrams were not available, neither were the design heat material balances, piping and instrumentation diagrams, and process descriptions. Other items, (i.e., the plot plan/general arrangement drawings and items #5 through #10 shown on Table 3-3), were provided in stages, and in some cases, only partially.

The experience with other audit sites indicates that the availability and quality of information varies significantly. It is important to make allowance for this possibility and to have a fall-back position. For example, if a piping and instrument diagram (P&ID) is not available, often times a piping layout plan will be. Similarly, if the information is not available from the facility, it does not mean that it cannot be obtained.

Much information is available from outside sources such as trade journals and vendors, e.g., the costs of bath make-up chemicals or the physical design of the process equipment. If information is truly needed but is not readily available, it can be obtained with proper initiative and ingenuity, but not without a possible detriment to project cost and schedule. In this light, it is important that only the information truly required to understand the process, to allow for delineation of waste sources and current waste management techniques, and to characterize waste generation quantitatively should be sought. Requesting unnecessary information burdens both the provider and user (auditor) and slows down the work.

The importance of the pre-audit activities, particularly the pre-audit site visits, were revealed as being extremely important in facilitating the audit process. At a facility where the audit team spent a little more time getting to know the host facility staff and how their organization functioned, the audit process moved more smoothly. The audit team found it easier and faster to acquire needed data because they knew better where (e.g., from whom) to obtain what data. Likewise, because they knew the operation and the people a little better, the level of cooperation by plant staff was improved.

It was observed during the audits that while waste stream selection helped to sharpen the focus of the effort, such selection should always be open to review and reassessment. An example is provided by facility C-2, described in Section 5 of this report. During selection, the generation of a cyanide-bearing sludge in the sump was attributed to the electroplating operation. During the formulation of waste minimization options, it was determined that the actual source of the sludge was from buffing and paint stripping operations, operations where cyanides are not used. Since total segregation of the cyanide-bearing electroplating waste and the non-cyanide-bearing sludges was impractical, the scope of the audit was expanded to include options regarding sludge reduction and elimination.

3.2.2 Audit Phase

The pilot studies experience led to a modification of the initially proposed audit method. The modified approach requires host facility personnel to independently develop ratings of each of the waste reduction options under consideration. The audit team's ratings of the options and the host facility's independent ratings can then be reviewed and reconciled in a group session. The initial approach of having the host facility personnel merely review and discuss the audit team's ratings following the presentation of the option ratings resulted in a relatively casual attitude and less involved behavior by the host facility staff.

Another observation is that the evaluation process may require several iterations, as the terms "waste reduction effectiveness", "extent of current use" and, especially, "future application potential" require assimilation by the host facility personnel. At both audits, a tendency was observed on the part of host facility reviewers to be fairly lax in the rating process. The audit team leader must convey the importance of this step to the team i.e., that the ratings will be used as the basis to screen the various measures.

3.2.3 Post-Audit Phase

The pilot studies also revealed the importance of how audit results (options and recommendations) are presented to plant personnel. In one case, when audit team members were extremely comprehensive and detailed in describing and explaining the rationales for the options under consideration, plant personnel began to lose interest in the deluge of information. It also was found that Good Operating Practices (GOP) recommendations must be presented with tact. In one case, host personnel initially considered a number of GOP recommendations as trivial, and even a little insulting ("don't you think we know all that already"). However, this reaction changed considerably when the estimated cost savings for strictly adhering to these GOP measures were provided.

In summary, a WM audit (and a WM program as a whole), requires effective communication and human interaction, as well as technical insight and engineering skills on the behalf of the audit team members. A successful WM audit program requires success in both the technical and human relations areas.

4. AUDIT REPORT FOR FACILITY C-1A/B

4.1 Facility Description

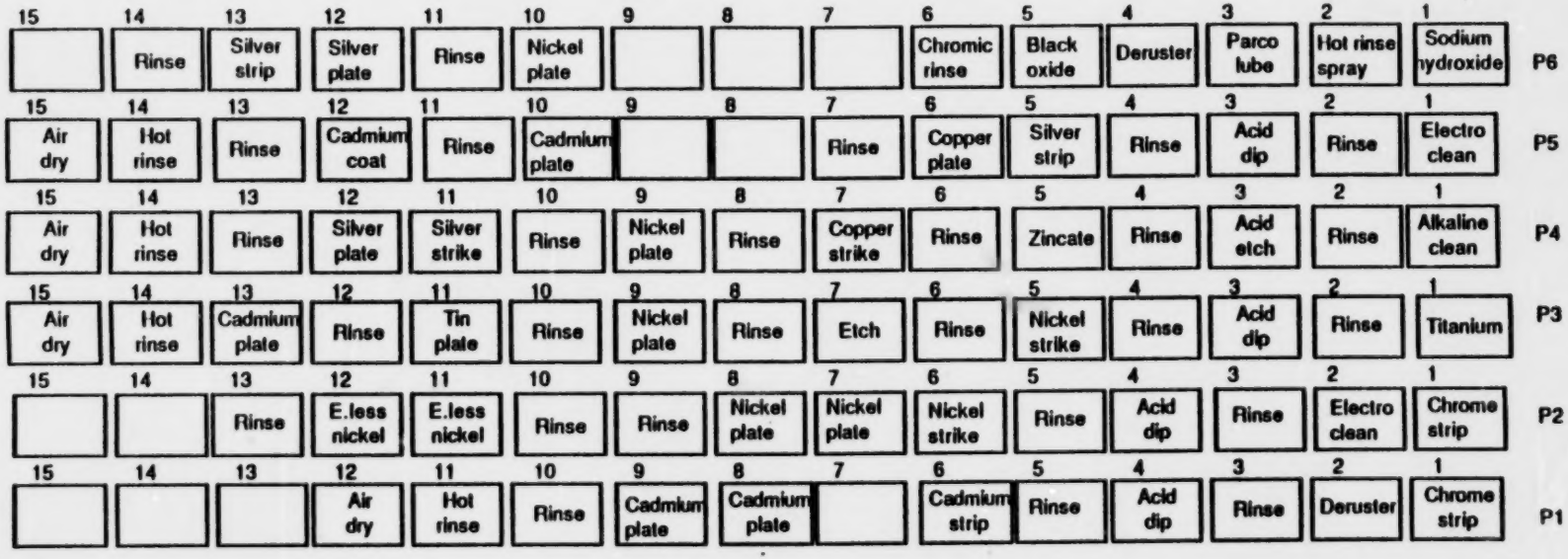
Facility C-1A/B, located in Southern California, is a major aviation, industrial, and seaport complex supporting anti-submarine aircraft, helicopters, and aircraft carriers of the Pacific Fleet. Facility C-1A operations are mostly performed by military personnel while Facility C-1B operations are performed by civilians. Cyanide wastes are generated from various operations associated with the facility C-1B plating shop. The principal metals plated at this facility are chromium, nickel, aluminum, copper, cadmium, and silver, which are often used to provide parts with a corrosion protection finish. Cyanide-based electroplating solutions involve copper, cadmium, and silver. Cyanide-based stripping solutions are used with silver only.

In addition to electroplating, vapor deposition techniques are also performed at the plating shop. A small vacuum chamber is used for cadmium plating and a much larger one has been installed for aluminum plating. Vapor deposition is used on parts that require a thick layer of plating (such as aircraft landing gear), while electroplating is used on parts that require a much thinner layer (such as nuts, bolts, and screws). Since the focus of this report is on ways to reduce cyanide wastes, the following discussion is restricted to operations involving the electroplating and stripping of cadmium, copper, and silver only.

All plating operations performed at the plating shop are done manually. There are two working shifts per day with a total of approximately 35 operators. Most of these operators have worked in the plating shop for a long time and they are very familiar with the many different types of operations performed at the facility.

4.2 Equipment Layout Description

Figure 4-1 provides a schematic diagram of the plating shop layout. Plating, rinsing, and cleaning tanks are arranged in six parallel rows of 12 to 15 tanks each. In each row, the sequence of tanks typically includes electrocleaning, rinsing, alkaline cleaning, rinsing, acid cleaning, rinsing, and various types of plating baths, each followed by a single rinse tank. Most rows end with a hot rinse tank and an air-dry tank. The dimensions of the cyanide-containing tanks are given in Table 4-1.



NOTES :

(a) All tanks containing cyanide plating solutions have filtering system except plating tank P6-12
(b) Copper plate tank P5-6 has not recently been used
(c) Only one of the cadmium plate tanks P1-8 and P1-9 is used at a time
(d) An empty box indicates that the corresponding tank is currently not in place

Figure 4-1 Plating Shop Layout

TABLE 4-1 DIMENSIONS OF CYANIDE-CONTAINING TANKS

Tank Number (a)	Description	Dimension (b)	
		Length (ft)	Width (ft)
P1-8	Cadmium Plate	11.00	4.00
P1-9	Cadmium Plate	11.00	4.00
P1-10	Rinse	5.75	4.00
P1-11	Hot Rinse	6.00	4.75
P1-12	Air Dry	6.00	4.00
P3-13	Cadmium Plate	6.00	4.75
P3-14	Hot Rinse	6.00	4.75
P3-15	Air Dry	6.00	4.00
P4-7	Copper Plate	6.00	4.75
P4-8	Rinse	5.75	4.00
P4-11	Silver Strike	6.00	4.75
P4-12	Silver Plate	6.00	4.75
P4-13	Rinse	5.75	4.00
P4-14	Hot Rinse	6.00	4.75
P4-15	Air Dry	6.00	4.00
P5-5	Silver Strip	6.00	4.00
P5-6	Copper Plate	6.00	4.75
P5-7	Rinse	6.00	4.00
P5-10	Cadmium Plate	5.75	4.00
P5-11	Rinse	5.50	3.85
P5-14	Hot Rinse	6.00	4.75
P5-15	Air Dry	6.00	4.00
P6-12	Silver Plate	4.20	4.20
P6-13	Silver Strip	4.20	4.20
P6-14	Rinse	4.20	2.70

(a) Location of tanks and associated numbers are given in Figure 4-1. Composition and bath volumes of plating/strip tanks are shown in Table 4-2.

(b) All tanks are 6.9 ft deep, with 3 ft of the tank above the floor level.

Table 4-2 lists the compositions of the cyanide-based stripping and plating baths, along with quantities of make-up compounds that have been added to the baths.

All tanks shown in Figure 4-1 are Plastisol lined. To comply with earthquake requirements, tanks containing cyanide-based plating/stripping baths have been converted to double-wall, with inner tanks made of 304 stainless steel. Most tank insertions were performed in May 1986. The effective volumes of some of the plating and stripping tanks were consequently reduced by as much as 57 percent. Due to space limitations and construction restrictions, diking of the original tanks for spill containment could not be done.

Plating solutions are continuously filtered in all cadmium, silver, and copper plating tanks (except for silver plate tank P6-12). Filtering is performed so that the plating baths remain free of solids that form during the plating operation. To enhance the effectiveness of the rinsing operations, most rinse tanks are equipped with air agitation devices. Agitation in plating and stripping tanks is done either by sparging air at the bottom of the tank or by mechanical propellers.

During operation, overflow from the rinse tanks is routed either to a cyanide sump or a general waste sump. The resulting wastewater from each sump is then pumped to the Industrial Wastewater Treatment Facility (IWTF). The flow of make-up water into the rinse tanks is level-controlled. Additions of make-up water into the plating or stripping baths are also done on a continuous basis using level-control feeders. Electronic level-control probes were found to be unreliable for use in these tanks.

In addition to the twenty-five cyanide-containing tanks indicated in Figure 4-1, there are two other silver strip tanks separately located in a corner of the plating shop (row P8). Although these tanks have not been used for several years, the most recent plan is to convert them into silver plating tanks. If this occurs, additional cyanide wastes would be generated from the use of this new silver plating line.

4.3 Process Description

The primary sources of cyanide waste come from various operations associated with cadmium plating, copper plating, and silver plating/stripping. On the average, about 800 to 1000 parts are plated daily. The maximum production capacity of the facility is

TABLE 4-2 COMPOSITIONS OF CYANIDE-BASED STRIPPING AND PLATING BATHS

Tank Number (a)	Bath Type	Bath Volume (gal)	Concentration Range (oz/gal) (b)	Makeup Cyanide Addition (lbs)	Time Interval
P1-9	Cadmium Plate	1356	2.5-4.5 Cd 6-10 free CN	400 NaCN	7/85 - 7/86
P3-13	Cadmium Plate	486	2.5-4.5 Cd 6-10 free CN	90 NaCN	7/85 - 7/86
P4-7	Copper Strike	475	0.5-1.5 NaCN 2-5 Cu	95-100 NaCN	1/86 - 8/86
P4-11	Silver Strike	165	8-12 KCN 0.4-0.6 Ag	70 KCN	4/85 - 7/86
P4-12	Silver Plate	475	17.5-22.5 KCN 1-2 KOH 7.5-9.0 Ag	25 AgCN	9/85 - 7/86
P5-5	Silver Strip	475	2-3 NaOH 12-14 NaCN	380 NaCN	9/85 - 7/86
P5-10	Cadmium Plate	486	2.5-4.5 Cd 6-10 free CN	60 NaCN	1/86 - 8/86
P6-12	Silver Plate	140	8-12 Ag 14-18 free CN 2-4 KOH	20 AgCN 120 KCN	9/85 - 7/86
P6-13	Silver Strip	140	2-3 NaOH 12-14 NaCN	50 NaCN	9/85 - 7/86

(a) Location of tanks and associated numbers are given in Figure 4-1.
(b) All tanks are operated at room temperature, with the exception of the copper strike tank P4-7 which is operated at 130-150°F.

estimated to range from 1400 to 1500 parts per day. Approximately twenty percent of all the parts processed utilize the cyanide-based plating/stripping baths.

The types of parts to be plated vary widely, ranging from large aircraft landing gear to simple nuts, bolts, and screws. As mentioned before, the required plating thickness varies depending on the parts. Precision silver plating can range from 0.08 to 0.1 mils thick, whereas copper and cadmium plating thickness typically ranges from 0.3 to 0.7 mils. The type of plating metal as well as the mode of plating to be used are specified by the engineering department.

Plating is performed using racks or barrels. It is estimated that at least 75 to 85 percent of all surface area plated by the facility involves the use of racks. Barrels are used for plating small parts (such as screws) that do not lend themselves to being rack mounted. While barrel-plating is used much less frequently than rack-plating, significant amounts of cyanide waste can be generated by this operation. This is due to the high level of drag-out often associated with barrel-plating.

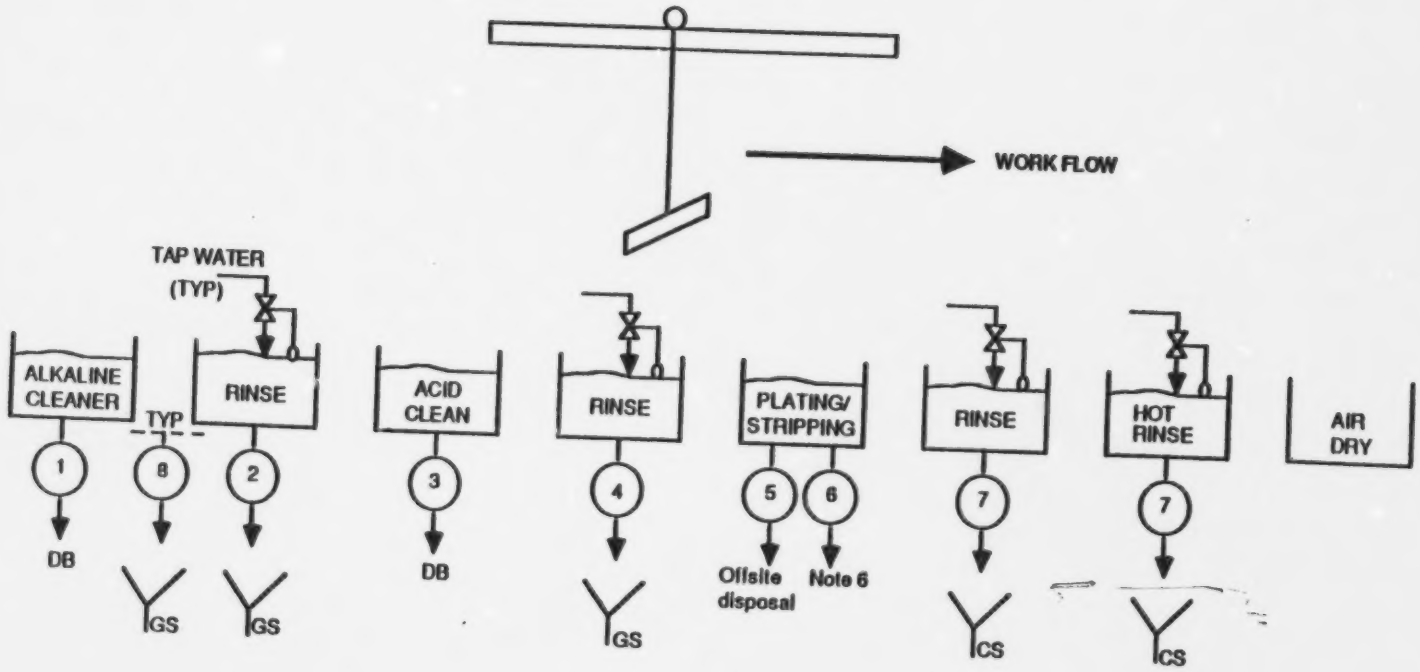
Figure 4-2 represents the process flow diagram for a typical electroplating operation. For both rack-plating and barrel-plating, the sequence of unit operations is very similar. The sequence includes the following operations:

1. Electrocleaning (optional): Parts are dipped into a cleaning solution (often alkaline). By passing an electric current through the parts, which produces gassing or tiny bubbles on the metal surfaces, the removal of dirt and oil is enhanced.

2. Rinsing (optional): A simple tank containing tap water often serves as the rinse tank. The water is air-agitated. Makeup water is continuously fed into the tank using a float type level controler. Since the flow control system does not include a flow meter, the amount of wastewater generated from rinsing operation was not quantified.

3. Alkaline cleaning: Barrel or rack mounted parts are dipped into a cold alkaline cleaning solution to remove oil and dirt.

4. Rinsing.



Notes : 1. Chemical make-up streams are not shown
2. CS = Cyanide Sump
3. GS = General Waste Sump
4. TYP= Typical
5. DB = Dry basin at IWTF
6. Replacement of spent plating solutions is not currently required. Spent silver stripping solutions are sent to an offsite waste treatment facility for silver reclamation.

(1) Spent alkaline solution
(2) Alkaline rinsewater
(3) Spent acid solution
(4) Acidic rinsewater
(5) Filter waste
(6) Spent plating/stripping solution
(7) Cyanide-containing rinsewater
(8) Spills

Figure 4-2 Electroplating Operation and Associated Waste Streams

5. Acid cleaning: After rinsing, parts are often immersed in an acid bath to remove oxides.

6. Rinsing.

7. Stripping (optional): When the old metal plate layer must be removed, the parts are dipped into a tank containing sodium cyanide stripping solution, and a reverse current is imposed upon the parts. The amount of immersion time required varies depending on the thickness of the metal layer to be stripped. The parts are then withdrawn from the strip tank at a predetermined rate to provide some degree of solution drag-out drainage.

8. Rinsing (optional).

9. Electroplating: The cleaned parts are then immersed in a plating tank containing the appropriate plating solution (copper, cadmium, or silver). As before, the immersion time and the withdrawal rate are preset by the operator. Most often, however, the parts are transferred from the plating bath to the subsequent rinse tank as soon as possible to prevent solution from drying on the parts and affecting the quality of the plating. Therefore, a very high level of drag-out can be expected for the plating operation.

10. Rinsing.

11. Hot rinsing: Most often, the final rinse step of a plating sequence is done using a warm water bath (120-140 ^{o}F) to thoroughly clean the plated parts and to speed up the subsequent drying operation.

12. Air drying: The plated parts are transferred to another tank to be air-dried. Hot air is produced and maintained at 160 ^{o}F by circulating air through a steam coil. This operation completes the plating operation sequence.

Concentrations of the principal plating bath components are checked periodically (weekly or biweekly) and make-up materials are added as required. Plating tanks are

completely cleaned once or twice a year. This operation normally takes a day to complete during which the plating solution is transferred to the adjacent rinse tank and the plating tank is thoroughly cleaned out. Because of the high degree of drag-out and the continuous filtering of the plating baths, routine replacement of the solutions is not required.

4.4 Waste Stream Description

The waste streams associated with a typical plating operation are schematically shown in Figure 4-2. Major waste streams include spent alkaline solution, alkaline rinse water, spent acidic solution, acidic rinse water, plating tank filter waste, spent plating/stripping solution, cyanide-containing rinse water, spills, and off-specification products. The following paragraphs describe each of these waste streams.

4.4.1 Spent Alkaline Solutions

Periodic replacement of contaminated alkaline cleaning solution constitutes the primary source of this waste stream. This waste generally does not contain cyanide unless previous rinsing operations were not adequately performed (parts plated with more than one metal require rinsing and cleaning in-between the plating steps). When this occurs, drag-in from the plating operations can introduce cyanide into the cleaning solutions. The spent alkaline bath is hauled off and dumped into a dry basin at the IWTF.

4.4.2 Alkaline Rinse Water

Overflow from the rinse tank immediately following an alkaline cleaning step is contaminated by drag-out from the cleaning bath. The resulting wastewater is piped to the general waste sump.

4.4.3 Spent Acidic Solutions

This waste stream is generated from the replacement of contaminated acid cleaning baths. The resulting spent acidic solution, which generally does not contain cyanide unless previous rinsing operations were not adequately performed (parts that are

stripped using cyanide-based solutions may require an acid etch before subsequent plating), is transferred to a dry basin at the IWTF.

4.4.4 Acidic Rinse Water

This wastewater stream is contaminated by drag-out from the acid cleaning bath and does not contain cyanide. As in the case of alkaline rinse water, this waste stream is transferred to the general waste sump.

4.4.5 Plating Tank Filter Wastes

Waste is removed from the plating tanks by the continuous filtering of the baths. Since the filtering system does not utilize an activated carbon layer to remove organic impurities, and since the carbonates formed in the plating solution are not chemically or physically removed by the filter, the discarded filtering medium will only contain solid impurities dragged in on the parts, solids due to decomposition of the anodes, and plating solution retained in the filter. The contaminated filter cartridges are replaced once every month, and are collected by the chemical handler to be disposed of as solid hazardous waste.

4.4.6 Spent Plating/Stripping Solutions

Periodic replacement of contaminated cyanide-based cadmium, copper, and silver plating baths is not required because drag-out provides adequate contaminant purging rate. Spent cyanide-based cadmium, copper, and silver silver stripping solutions are sent to a government-owned waste treatment facility for treatment and metal (silver) reclamation.

4.4.7 Cyanide-Containing Rinse Waters

This waste stream consists of overflow from rinse tanks used after a cyanide-based plating or stripping operation. The wastewater is contaminated mainly by the drag-out from the plating or stripping tanks. These wastewater streams are collected in the cyanide sump and are routed to the IWTF.

4.4.8 Spills, Leaks, and Drippings

This stream contains wastes resulting from tank leakage, from accidental overflow of the plating/stripping tanks due to failure of the make-up water flow control devices, and from the dripping of solutions from parts during their transfer between tanks. Spills and solution drips are collected by catch basins and transferred to the cyanide sump. Significant spills due to plating tank overflow or leakage have never been reported with the cyanide plating operation.

4.4.9 Waste Due to Off-Specification Products

Defective parts can result from inadequate cleaning as well as inappropriate plating conditions. It is estimated that about 2 to 3 percent of all the parts plated are normally rejected. Since these parts must be stripped and replated, generation of off-spec products does generate additional amounts of cyanide wastes.

4.5 Current Waste Management Profile

As discussed above, the primary sources of cyanide loss are from drag-out of plating/striping solutions, which then enter the wastewater, and from plating solution filtrate, which is retained in the filtering medium and disposed of as solid waste. In 1978, a separate cyanide waste treatment unit was constructed outside of the plating shop to treat the wastewater coming from the cyanide sump. This unit did not perform as expected and was soon abandoned. Reasons for the system's poor performance included lack of adequate operational attention and, presumably, monitoring problems due to very low inlet concentration of cyanide in the wastewater. Presently, wastewater from the cyanide sump is mixed with other waste streams and pumped to the IWTF.

It is estimated that approximately 650,000 gallons of wastewater are treated daily at the IWTF. About 5 percent of this is estimated to originate from cyanide-based plating operations. It is estimated that about $350,000 is spent each year to dispose of approximately 700 tons of wastewater treatment sludge. No attempt is made to recover precipitated metals from the sludge produced. Since the focus of this report is on source reduction, treatment of wastewater from plating operation will not be discussed in this section.

4.6 Postulated Waste Minimization Options

In this section, the options that were originally postulated or considered as potentially suitable for reducing waste generated from the plating shop are described, along with the associated pros and cons. Whenever possible, quantitative assessment is also provided.

Although the plating of different metals requires the use of various plating solutions and operating conditions, most waste reduction options are generally applicable to a wide variety of electroplating processes. Therefore, unless otherwise stated, it is assumed that the waste minimization methods discussed in this section are applicable for cadmium, copper, and silver plating, as well as for silver stripping operations.

Waste minimization options for facility C-1B can be grouped into six distinct categories. These categories include drag-out minimization, bath life extension, rinse water minimization, substitution of non-cyanide solutions, substitution of alternate plating metals or techniques, and good operating practices. The following sections discuss each waste reduction option in detail.

4.6.1 Drag-Out Minimization

By minimizing the amount of drag-out carried from a plating, stripping, or cleaning bath to a rinsing bath, less of the plating solution constitutents will leave the process, which ultimately leads to savings in raw materials and treatment/disposal costs. The amount of drag-out depends on the following factors:

1. Bath concentration. Highly concentrated solutions increase both the drag-out volume (increased viscosity) as well as the amount of material loss per unit of drag-out volume.

2. Surface tension of the plating solution. A plating solution with a high surface tension tends to be retained in the crevices and surface imperfections of the workpiece when it is removed from the plating bath, thus increasing drag-out.

3. Viscosity of the plating solution. Highly viscous solutions result in increased drag-out.

4. Physical shape and surface area of the workpiece. The shape of the workpiece affects the amount of plating solution that gets dragged out of the bath. Parts with many crevices and recesses can retain large amounts of plating solution. In addition, the size and shape of the part holder can also affect the amount of drag-out. In general, barrel plating causes more drag-out than rack plating.

5. Speed of workpiece withdrawal and drainage time. The rate at which the workpiece is withdrawn from the tank, the time allowed for drainage of the part over the tank, as well as the orientation with which the work is withdrawn from the tank, all affect the amount of drag-out produced.

Six drag-out minimization techniques have been addressed, as described below. Of these, only the first measure, which involves proper positioning of workpieces on rack, is currently being used at the plating shop.

- Properly position the workpiece on the plating rack.

When a workpiece is lifted out of a plating solution on a rack, some of the excess solution on its surface (drag-out) will drop back into the bath. Proper positioning of the workpiece on a rack will facilitate the dripping of the drag-out back into the bath. The position of any object which will minimize the carry-over of drag-out is best determined experimentally, although the following guidelines were found to be effective (USEPA 1981):

- Orient the surface as close to vertical as possible.
- Rack with the longer dimension of the workpiece horizontal.
- Rack with the lower edge tilted from the horizontal so that the runoff is from a corner rather than an entire edge.

- Lower the concentration of plating bath constituents.

By maintaining the plating solution at the lower level of the allowable concentration range, the amount of salt constituents in the drag-out is reduced. Also a decrease in the concentration of metal salts and other components of the plating solution leads to lower solution viscosity. Lower concentration thus results in less drag-out volume, lower metal losses, and reduced rinsing requirements. This practice may not be applicable if the plated parts have deep recesses, however, since the lowered concentration level may reduce the throwing power of the plating bath.

Another major drawback of this option would be the increase in maintenance and testing requirements needed to operate the plating unit under the more demanding conditions. It will be necessary to provide closer monitoring of the plating solution so that adequate plating performance is maintained. The frequency of bath constituents testing may have to be increased from biweekly to weekly or even more often. The frequency of make-up materials addition will have to be increased. In addition, voiding of the plating solution manufacturer's warranty is a concern encountered by some firms trying to apply the option.

- Reduce the speed of workpiece withdrawal from solution and allow ample drainage time.

The faster the workpiece is removed from the bath, the higher the drag-out will be. The workpiece should be removed as slowly and as smoothly as possible. Ample time should be allowed for draining the solution back to the tank. Usually, 30 seconds allows most of the drag-out to drain back to the tank. However, in applications where quick drying is a problem, a 10 second draining period still permits good drag-out recovery. In addition, barrels should be rotated to improve drainage.

- Increase the plating solution temperature.

Increasing plating solution temperatures lowers both the viscosity and surface tension of the solution, thus reducing drag-out. The resulting higher evaporation rate may also inhibit the carbon dioxide absorption rate, slowing down the carbonate formation in cyanide solutions. This benefit may be lost, however, due to the increased rate of formation of carbonate resulting from the breakdown of cyanide at elevated

temperatures. With the exception of the copper strike tank, which is operated at 130-150 °F, all other plating tanks are presently operated at room temperature (75 °F). Cyanide cadmium plating baths may generally be operated at temperatures of up to 90 °F with no adverse effects (Mills et al. 1983). Electric immersion heaters can be used to supply the additional heating requirement. Preliminary estimates indicate that drag-out volume reductions in the 10-20% range can be achieved due to lowering viscosity by increasing solution temperature from 75°F to 90°F.

The primary disadvantages of this option would include higher energy costs and a higher chance of contamination due to increased make-up requirements. These additional costs may be partially offset by the savings in treatment and/or disposal if the measure is adopted in conjunction with the implementation of a more effective rinsing system.

- o Use surfactants to lower the surface tension of the solution.

Applied in only small amounts, wetting agents can lower a solution surface tension enough to reduce drag-out by up to 50% (USEPA 1981). Only nonionic wetting agents, which will not be degraded by electrolysis in the plating bath, should be used. The use of surfactants is sometimes limited due to their adverse effect on the quality of the plate produced. For example, some brighteners which also possess wetting property can be added to cadmium cyanide plating solutions. These materials, however, will produce stress on the deposit and increase the degree of hydrogen embrittlement in the plated part. It may be worthwhile, nevertheless, to conduct a search for an appropriate wetting agent to be used with a particular plating bath.

- o Improve drag-out recovery.

A drain board positioned between a plating bath and rinse bath can capture the dripping solution off a workpiece and channel it back to the plating bath. This is a simple but very effective operation and can be incorporated into the present electroplating process. The drain board can be made of either plastic, metal, or any other non-reactive materials. In cases where spatial limitation is not a major problem (e.g., during low-production periods in which some existing tanks are not in use), another commonly practiced option is to incorporate a drip tank between the plating bath and the rinsing bath. The drip tank is an empty tank for collecting the dripping

solution, which can be returned to the plating bath. In addition to drain boards and/or drip tanks, air knives can be used to knock plating film off parts back into the process tanks. This practice is applicable for rack-plating only.

In addition to the use of direct drag-out reduction methods discussed above, drag-out from plating/stripping tanks can also be recovered during the rinsing operation. This can be done using still rinsing. Installing a still (or "dead") rinsing tank immediately after a plating bath allows for metal recovery and lowered rinse water requirements. In such a system, the workpiece is immersed in a still rinse tank following the plating bath. Since the still rinse has no inflow or outflow of water, the concentration of the plating bath constituents builds up. When the concentration level becomes sufficiently high, the contents of the still bath are used to replenish the plating bath (Durney 1984, Cushnie 1985).

4.6.2 Bath Life Extension

The lifetime of a plating solution is controlled by the rate of accumulation of impurities and/or by the rate of depletion of constituents due to drag-out. Reduction of drag-out will lead to increased rates of impurity buildup in the solutions since these impurities are normally purged by the drag-out. If the impurity buildup is excessive, inadequate performance will result and the contaminated solution must be discarded. The resulting waste is highly concentrated with toxic compounds and requires treatment.

The impurities come from, at least, five sources: racks, anodes, drag-in, water make-up, and air. The impurities buildup can be limited by the following eight techniques, four of which have been fully or partially implemented at the present plating facility; these include drag-in reduction by better rinsing, use of deionized or distilled water, bath impurity removal, and proper rack design and maintenance.

- Drag-in reduction by better rinsing.

Efficient rinsing of the workpiece reduces the drag-in of plating solution into the next bath.

- Use of deionized or distilled make-up water.

To compensate for evaporation, water is required for makeup of plating solutions. Using deionized or distilled water is preferred over using tap water, since tap water may have a high mineral or solids content, which can lead to impurity buildup. Currently, deionized water is used for plating/stripping tanks, while tap water is used as rinse water.

- Plating/stripping solution regeneration through impurity removal.

Several methods have been successfully used to increase the longevity of plating solutions through impurity removal. Particulates can be removed from the plating solution by periodic or continuous filtering (McRae 1985). Metallic impurities can sometimes be chemically removed from the plating bath. For example, for cadmium cyanide plating solution contaminated by impurities such as copper, tin, lead, or other metals, the bath can be periodically treated by adding purified zinc dust to the solution. The precipitates can then be removed by filtration. An auxiliary tank should be used for the purification step to insure proper plating quality (Mills et al. 1983).

In cyanide baths, carbonate tends to build up in solution over time due to CO_2 absorption from the air and/or from cyanide oxidation. This leads to solution deterioration. Reducing the carbonate concentration in baths containing sodium salts can be accomplished using a technique developed by the U.S. Army, which involves freezing the carbonates out of solution (Pearlstein and Evans 1982). A metal box containing dry ice and water is immersed in the plating bath. Carbonates are precipitated directly onto the outside metal surface of the box, which is then removed from the solution. The carbonates are scraped off the box and discarded as hazardous solid waste, with a volume and toxicity considerably lower than that of the sludge associated with the spent plating solution. For solutions containing potassium salts, carbonates must be chemically removed by methods involving the addition of calcium sulfate or barium cyanide to the baths (Lowenheim 1979).

- Use mechanical agitation instead of air sparging.

A more practical approach would be to lessen CO_2 access to the plating solution by converting from air-agitation to mechanical agitation of the plating tank (e.g., using a

pump around). This would greatly limit the interface area between the CO_2-bearing air and the plating solution.

- o Proper rack design and maintenance.

Corrosion and salt buildup deposits on the rack elements will contaminate plating solutions upon chipping and falling into the solution. Proper design and maintenance (cleaning and inspection) will minimize this form of contamination.

- o Purer anodes.

During the plating process, metal from the anode is dissolved in the plating solution and deposited on the cathode (workpiece). Most of the impurities contained in the original anode matrix will stay behind in the plating solution, eventually accumulating to unacceptable levels. Thus, the use of purer metal anode will extend the plating solution life (Mills et al. 1983). In addition, anode bags (e.g., made of cotton) should be used to prevent the solid impurities generated at the anode from entering the bath (Mills et al. 1983).

- o Proper anode removal.

If a cadmium cyanide solution is to be left idle for an extended period of time (a week or more), the steel anode cages should be removed from the solution, because the galvanic cell set up between the steel and cadmium anode will accelerate chemical dissolution of the anodes when the plating current is off (Mills et al. 1983). The metal concentration, therefore, may increase over the allowable range and can adversely affect the performance of the plating solution.

- o Return solution to manufacturer.

This option requires on-site segregation of solutions according to the metal in the solution. The applicability of this measure will depend on whether or not the manufacturer of the plating solution is willing to accept and reprocess the spent baths.

4.6.3 Rinse Water Minimization

The currently used procedure at the plating shop employs immersion of workpiece in a single flow-rinse bath following a plating bath. Several methods exist which use less water than the flow-rinse method, while still adequately rinsing the workpiece. Although reducing the amount of rinse water usage does not directly reduce the cyanide waste generation, improvement in the rinsing system may lessen the likelihood of inadequate plating performance resulting from contamination, and thus reduce the waste generation associated with the remanufacturing of off-spec products. In addition, implementation of an effective water usage system can make the subsequent wastewater treatment step more effective. For example, if rinse water usage can be significantly reduced, this will increase the cyanide concentration in the wastewater from the plating shop to a level such that it can be treated using the present cyanide treatment unit. In some cases, implementation of an effective rinsing system can also prevent the generation of cyanide-containing wastes from otherwise cyanide-free sources. Such situation will arise when drag-in of cyanide-based solutions from the previous plating cycles due to inadequate rinsing is introduced into the cleaning solutions.

Of the following common measures used to minimize water usage and to improve rinsing, only the use of automatic flow control and the use of bath agitation have been adopted at the plating shop.

- Automatic flow controls.

Conductivity probes and controllers can be used to automatically control the flow (Cushnie 1985). This control system has been found to be not very reliable for operation at the plating shop, however.

- Rinse bath agitation.

Agitating a rinsing bath mechanically or with air increases the rinsing efficiency and cuts down on flow-controlled water usage (Durney 1984).

- Multiple rinse tanks.

The use of multiple rinse tanks is one of the most commonly used source reduction techniques. Multiple rinsing tanks can reduce rinse water requirements by up to 66%, with possible theoretical reductions of over 90% (Mills et al. 1983, USEPA 1983, Olsen 1973). Multiple rinse tanks are aligned either in series or in parallel. When space limitation is a problem, dams can be welded across an existing tank, which would result in improved rinsing efficiency, providing that the original tank is large enough to accommodate the required workpieces.

In the parallel arrangement, each rinsing tank is individually fed with fresh rinsing water. The more effective series arrangement differs in that it is a counterflow system. In a three tank counter-current system, the workpiece enters the first rinse tank, which has the most contaminated rinse water. It is then moved to the second tank, and then to the last, where it contacts fresh rinse water. Fresh rinse water enters only the last (third) rinsing tank. The water from the third tank then flows into the second tank, then into the first tank, from which it can be routed into treatment and/or to the plating tank as a make-up.

Unless a much higher production rate is expected in the near future, it is suggested that where possible, the empty tanks at the plating shop be converted into multiple rinse tanks.

- Spray and fog nozzles.

In cases where spatial limitation present a great problem, effective rinsing can still be achieved through the use of sprays and nozzles. Spraying water droplets directly onto a workpiece is much more efficient than immersing a workpiece into a liquid water bath (Durney 1984). A major limitation is that spraying is not effective on oddly-shaped objects, since the spray cannot make direct contact with the entire surface of the object. An alternative to the spray nozzle is the fog nozzle, which uses water and air pressure to produce a fine mist. Fog nozzles consume much less water than spray nozzles (Durney 1984). Spray or fog rinsing is used on rack plating. Nozzles are generally not applicable for barrel plating because the spray cannot reach the parts located inside the barrel.

- Closed-loop rinsing and rinse water reuse.

Generally, rinse water in a closed-loop rinsing arrangement can be recovered by evaporation and reused. However, in closed-loop systems, care must be taken to minimize impurity drag-in from preplate operations. In addition, it may be justified sometimes to increase the bath evaporation rate (e.g., by increasing the temperature), and to use recirculated spray rinsing to reduce rinse water usage. The remaining rinse water can be used as make-up water for the bath. This measure is more beneficial for high temperature processes (e.g., copper plating) where the evaporation loss is large.

- Proper barrel rinsing arrangement.

For barrel plating, rinsing is most efficient when barrels are immersed only partially in the rinse tank (Durney 1984).

4.6.4 Substitution of Non-Cyanide Solutions

A variety of non-cyanide plating and stripping solutions can be used as substitutes for cyanide-containing baths. The use of alternate plating/stripping solutions, however, has been limited due to the inability of the alternate solution to meet the required specifications of a particular part. Nevertheless, it is suggested that attempts should be made at least, to test new solutions on a small scale to see if the bath is adequate for the required specification. The following alternates to cyanide-based solutions were considered:

- Pyrophosphate copper plating solution.

Pyrophosphate copper plating solutions can be used in place of cyanide-based solutions for heavy copper plating (Mills et al. 1983). The pyrophosphate solutions, however, often have lower throwing power than cyanide-based solutions and cannot be used successfully where many different base metals are plated.

- Non-cyanide cadmium plating baths.

Non-cyanide plating baths can be used to satisfactorily plate cadmium for a wide variety of applications. These may include ammonium chloride, ammonium fluoborate,

ammonium sulfate, acidic cadmium oxide, and cadmium fluoborate baths (Mills et al. 1983). Of these, the fluoborate baths, having a reasonably high throwing power, are the most attractive alternatives to the conventional cyanide-based solutions. The performance of acidic non-cyanide cadmium bath (e.g., the "Cadize Plating Solution" formulated by Learsonel Inc.) has also been proven by an Air Force installation located in Marietta, Georgia, to be satisfactory without any noticeable adverse effects on the quality of the plated parts (Higgins 1985).

Replacing cyanide solutions with non-cyanide solutions, however, often requires upgrading of the degreasing/cleaning techniques used. This is because the non-cyanide replacements often will have a much lower tolerance for impurities, and therefore require a much more thoroughly cleaned surface to ensure high quality plating. In addition, military specifications often require the use of cyanide solutions, thereby preventing voluntary use of non-cyanide replacements.

- Non-cyanide silver stripping solutions.

Stripping of silver from steel parts can be done using a bath of potassium nitrate and ammonium hydroxide instead of cyanide-based stripping solutions.

4.6.5 Substitution of Alternate Plating Metals and/or Techniques

Cadmium is used in a wide variety of products for its excellent protective properties. Cadmium-plated products are highly resistant to corrosion. For this reason, the U.S. military specifies cadmium plating for a large variety of naval and aerospace equipment. Since cadmium is mostly plated from cyanide-based electroplating solutions, replacement of cadmium electroplating with other plating metals and/or techniques can significantly reduce the generation of cyanide waste from the plating shop.

The most favorable alternatives to cyanide-based cadmium electroplating include vapor deposition of cadmium or aluminum. Both of these methods are currently being tried at the plating facility.

- Cadmium ion vapor deposition.

Cadmium ion vapor deposition is presently performed in the plating shop to plate some types of parts. Complete conversion of cadmium plating form cyanide-based electroplating to vapor deposition has not been because: 1) some parts having odd-shapes with blind areas can not be adequately plated using the present vacuum chamber configuration, and 2) cadmium vapor deposition is much more complex and requires more labor and skills than the conventional electroplating process.

In the context of hazardous waste minimization, it may be beneficial, however, to reconsider the option of changing from electroplating to vapor deposition. A new vacuum chamber can be designed with provisions to allow for plating of a wide variety of parts. Savings from lower hazardous waste disposal costs should be taken into account during the economic feasibility analysis of this option. Due to economies of scale, the benefit resulting from a lower cyanide waste generation rate may be lost, however, if a cyanide treatment unit is constructed to treat wastewater from the plating shop.

- Aluminum ion vapor deposition.

This attractive alternate plating technique, which can eliminate both cyanide and toxic cadmium waste, is presently being tried at the plating shop. The primary disadvantages of aluminum vapor deposition include the system's complexity, high capital cost, and high operating cost (due to labor requirements). In addition, aluminum cannot provide adequate protection to some parts. Nevertheless, the environmental advantages favor the switch from cadmium to aluminum plating to the extent possible.

4.6.6 Good Operating Practices

Good operating practices (GOP) are defined as procedural or institutional policies that result in a reduction of hazardous waste generation. The general objective of GOP is to minimize material losses and the probability of their occurrence. GOP normally encompasses changes that can be made to the human aspects of production. Although currently being implemented to various extents (except for the last method listed below), the following elements of GOP should be carefully considered in the development of a program to reduce hazardous waste generated from plating operations.

- o Waste stream segregation.

Proper waste segregation can significantly reduce the amount of hazardous waste that must be ultimately disposed of, since it can promote efficient recycling or treatment options. Presently, cyanide waste is kept segregated from other wastes at the plating shop. However, it is mixed with other wastes downstream in the industrial sewer prior to entering the IWTF. It is suggested that the cyanide waste stream should be kept separate from other wastes and treated separately by an existing (but unused) unit.

- o Operator training and closer supervision.

Since all plating operations are done manually, closer supervision, coupled with an efficient operator training program can lead to substantial reduction in waste generation (e.g., by provision of adequate time for drainage). Increased awareness of the necessity to reduce waste generation would help the operator in making better judgements during operation.

- o Spill and leak prevention.

The likelihood of spills can be lessened by 1) equipping all tanks with overflow alarms, 2) routine inspections for leaks, 3) improving operational control for loading/unloading and transfer operations (e.g., whenever a major transfer operation is performed, the supervisor should oversee the operation), 4) isolating equipment or process lines that are not in service, and 5) documenting the spillage and related dollar values for future improvements in clean-up procedures and prevention measures.

The structural soundness of the tanks can be assured through inspection and record-keeping initiatives. Monthly visual inspection of tanks, including all equipment connected to them, the tanks' seams, and the supporting structures, should be conducted. All these efforts can be conducted in coordination with other existing safety and operation checks.

Spills are most likely to occur during loading/unloading operations and in-plant transfer activities. For this reason, written procedures should be kept current and made easily accessible to all employees. In addition, a spill response plan should be formulated, and employees should be trained both in the current operating procedures

and in the correct implementation of emergency spill measures. A policy of taking disciplinary action on violations, if strictly enforced, can ensure employees' adherence to proper procedures.

o Preventive and corrective maintenance.

Effective maintenance can be instrumental in cutting production costs resulting from repairs, related waste disposal, and production interruptions. Computers can be used to facilitate the development of a successful maintenance program, as well as to provide adequate material controls and monitoring (Katzel 1986). The following preventive measures can be taken to reduce waste generation from plating operations.

- Perform frequent inspection of plating racks for loose insulation.

- Perform frequent analysis of the plating baths and rinse tanks to ensure that the contamination levels are not excessive.

- Optimize/maintain design operating conditions.

Often, improvement in plating performance can be obtained through reexamination and appropriate alteration of the design parameters of an existing plating system. For example, pulse plating improves speed, throwing power, and distribution; also, the use of conforming anodes can improve plating quality. Once the optimum plating conditions have been selected, operating parameters such as temperature, current density, concentrations, and agitation should be kept as close as possible to the design values to ensure proper plating/stripping performance. In addition, any significant deviations from the design operation and/or production level should be promptly recorded so that appropriate correction to the operating conditions can be made.

o Management initiatives.

Management initiatives are often taken to promote or improve the facility waste reduction program. These can be accomplished in several ways, such as through the conducting of environmental and/or waste minimization audits, the provision for

environmental/safety review of operations, or the establishment of employee waste reduction awareness and reward programs.

- o Material/waste tracking and inventory control.

Accurate material balances, product, and waste tracking along with clear process documentation provide operation supervisors with information of the inventories and movement of hazardous materials. This allows for timely detection and correction of a problem and for efficient operation control. Computers are increasingly being used in industry to monitor inventories and track materials through production processes (Giltenan 1984).

4.7 Screening of Cyanide Waste Minimization Options

Table 4-3 lists the various waste minimization measures noted above for each control category. Each measure has been rated on a scale of zero (low) to ten (high) in three categories: waste reduction effectiveness, extent of current use, and future application potential. The future application potential is a qualitative measure of how difficult that measure would be to implement due to technical and/or financial obstacles. The ratings were originally provided by project staff and then were reviewed by the staff of the host facility.

After rating each measure, the current and future reduction indices were determined in accordance with the procedure listed in Section 3.1.7. Each index was computed on a scale of zero to ten, with the value of ten indicating that total elimination of the waste is possible. The current reduction index is a qualitative measure of the degree to which waste has been already minimized by use of the listed methods. The future reduction index is a qualitative measure of the degree to which the existing waste can be minimized by implementation of the listed methods. For each control category shown in Table 4-3, the highest future reduction index has been marked by an arrow.

4.8 Feasibility Analysis of Selected Waste Minimization Options

Through a joint review of the ratings of each proposed waste minimization option, a set of top-ranking options was selected for additional evaluation and analysis. The following options in the categories of drag-out minimization, bath life extension, rinse

TABLE 4-3 SUMMARY OF WASTE MINIMIZATION OPTIONS FOR FACILITY C-1A/B

Control Category	Control Methodology	Waste Reduction Effectiveness	Extent of Current Use	Future Application Potential	Current Reduction Index		Future Reduction Index
Drag-out Minimization	1. Proper positioning of parts on rack	4	4	7	2		2
	2. Lower bath constituents concentration	5	0	4	0		2
	3. Reduce speed of withdrawal of parts	6	0	5	0		3
	4. Increase bath temperature	2	0	2	0		0
	5. Use of surfactants	3	0	2	0		1
	6. Improve dragout recovery	8	0	10	0	===>	8
Bath Life Extension	1. Dragin reduction by better rinsing	5	5	8	3		2
	2. Use deionized or distilled water	4	8	10	3		1
	3. Bath impurity removal	8	5	8	4		3
	4. Mechanical vs. air agitation	8	0	8	0	===>	6
	5. Proper rack design & maintenance	4	5	10	2		2
	6. Purer anodes	2	0	2	0		0
	7. Proper anode removal	2	0	4	0		1
	8. Return spent solution to manufacturer	8	0	1	0		1
Rinse Water Minimization	1. Automatic flow control	4	5	8	2		2
	2. Rinse bath agitation	3	8	10	2		1
	3. Multiple rinse tanks	6	0	2	0		1
	4. Fog nozzles and sprays	6	0	5	0	===>	3
	5. Close-loop rinsing & wastewater reuse	6	0	2	0		1
	6. Proper barrel rinsing arrangement	3	0	2	0		1
Substitution of Non-cyanide Solutions	1. Pyrophosphate copper plating bath	5	0	0	0		0
	2. Non-cyanide cadmium plating bath	8	0	5	0	===>	4
	3. Non-cyanide silver stripping solution	8	0	2	0		2
Substitution of Plating Metals or Techniques	1. Cadmium ion vapor deposition	8	7	8	6	===>	2
	2. Aluminum ion vapor deposition	8	8	9	6		1
Good Operating Practices	1. Waste stream segregation	6	2	5	1		2
	2. Operator training/ closer supervision	8	6	10	5		3
	3. Spills and leaks prevention	8	8	10	6		2
	4. Preventive/ corrective maintenance	8	5	10	4	===>	4
	5. Management initiatives	5	5	8	3		2
	6. Material/ waste tracking	5	0	5	0		3

water minimization, and substitution of non-cyanide solutions, were chosen as candidates for analysis:

1. Reduction of drag-out using drain boards and extension of bath life through impurity removal.
2. Reduction of drag-out using drain boards and extension of bath life through conversion to mechanical agitation.
3. Recovery of drag-out using still rinsing.
4. Reduction of water usage using spray rinsing.
5. Substitution of non-cyanide cadmium plating solutions.

For the remaining categories, no further evaluation of the proposed options was performed either because the methods' FRI values were low or because these methods involve changes that are operational in nature (e.g., better operator training), and which can be addressed directly by the facilities' operational staff. The following sections discuss each option analysis in detail.

4.8.1 Drag-Out Reduction Using Drain Boards and Extention of Bath Life Through Impurity Removal

A drain board made of steel, plastic, or any other non-reactive material can be used to recover solution drag-out during drainage of workpieces. The board should be placed slightly sloped toward the plating or strip tank, so that the drained solution can be routed back to the bath. Once fastened to the tanks, the drain board can also serve as a workpiece rest area. The drain boards should be cleaned periodically to prevent the accumulation of dirt and the resulting drag-in of contaminants into the subsequent plating/stripping baths.

It has been estimated that for rack plating, the amount of solution drag-out can be lowered by up to 90% if the part is well drained (Durney 1984). Assuming a maximum 90% reduction in drag-out, the ability of the solutions to operate at increased impurity levels, and the use of a 2 ft by 4 ft PVC drain board with each of the 9 cyanide-containing plating/stripping tanks, the costs and savings associated with the use of drain boards were estimated and the results are given in Table 4-4.

TABLE 4-4 ECONOMIC ANALYSIS OF DRAG-OUT REDUCTION USING DRAIN BOARDS ONLY

INSTALLED COSTS	
Drain Boards (9), delivered cost including sales tax (a)	$690
Installation including labor and supplies	200
Total Installed Costs	$890
INCREMENTAL SAVINGS, MONTHLY	
Make-up Materials (b)	$396
Treatment Costs (b)	364
Disposal Costs (b)	24
Savings	$784
PAYBACK PERIOD, MONTHS (c)	1.1

(a) Based on 2 ft by 2 ft PVC boards.

(b) Assumed 90% reduction in drag-out. Savings in make-up materials, treatment, and disposal costs were calculated from data given in "Electroplating Engineering Handbook, 1984" (Durney 1984), adjusted for the actual reduced drag-out rates from the plating shop. It is further assumed that the cost associated with silver plating is the same as the rates given for cadmium plating.

(c) Payback period equals total installed cost divided by savings. Depreciation, taxes and fees were not included in the calculation of payback period.

The estimates for savings in make-up materials, treatment, and disposal costs were calculated from available cost data given in the literature for the electroplating of copper and cadmium (Durney 1984). This data is based on a drag-out value of 1 gal/hr for an 8-hour workshift. These costs were adjusted to match with the actual drag-out rates observed in the plating shop. It is estimated that the drag-out rates from copper plating, cadmium plating, and silver plating/stripping are 3.3 gal/shift, 0.85 gal/shift, and 1.32 gal/shift, respectively. The drag-out estimates were derived based on material balances performed on the make-up cyanide-containing compounds that were added to the baths (Table 4-2).

It should be noted that the savings in avoided treatment costs will not be realized in the present mode of operation, since the rinse water is not presently treated for cyanide destruction. Savings in disposal costs (excluding transportation cost) were obtained, based on the current rates charged by a commercial hazardous waste handling company.

Since drag-out provides a means of purging impurities from the plating/stripping bath, any effort to reduce drag-out must be accompanied by an effort to remove or limit the accumulation of impurities. Build-up of impurities to excessive levels could adversely affect the quality of the plating operation.

For plating as well as stripping, it would be necessary to increase solids removal by continuous filtering of the solutions. Since all cyanide-containing plating/stripping tanks are presently filtered continuously, the only additional cost due to the reduction in drag-out would be the replacement and disposal cost of the additional filter cartridges. It is estimated that for a 90% reduction in drag-out, the filter replacement frequency for each plating or stripping tank may increase from 1 to 4 cartridges per month. An increase in cost if all 9 cyanide-containing tanks are filtered continuously was estimated at 95 dollars per month, based on cartridge replacement cost only.

In addition to continuous filtering, it would be necessary to limit the carbonate buildup in the plating baths. Such limiting would be considered only for copper and cadmium baths, where detrimental effects of carbonate buildup are known and documented. It could not be ascertained whether carbonate formation in silver baths is detrimental.

The copper and cadmium plating tanks are agitated by sparging air through a one-inch pipe distributor located at the bottom of the tank. Atmospheric carbon dioxide is absorbed into solution primarily from the air used in sparging. Absorption through the top liquid surface was ignored. Based on the assumptions that the air flows at a velocity of 75 ft per second, and that 100% of the carbon dioxide is absorbed (a very conservative assumption), it is estimated that the carbon dioxide absorption rate is approximately 0.36 lb/hr per tank, which is equivalent to 0.87 lb/hr of sodium carbonate formation rate.

For cadmium plating, the available literature indicated that the concentration of sodium carbonate in the solution generally should not exceed a value of 4 oz/gal (Mills et al. 1983). Exceeding this concentration results in anode polarization, in depletion of the metal content of the bath, and in poor, irregular, and dull deposits. The allowable carbonate concentration limit varies depending on the type as well as the concentration of metal in the bath. For adequate copper plating, the sodium carbonate concentration should not exceed 20 oz/gal (Mills et al. 1983) although a 6-8 oz/gal limit has also been quoted by one of the consultants. Based on these upper concentration limits and the rate of formation of sodium carbonate in the aerated plating tanks, it is estimated through mass balance that approximately 43.7, 48.7, 48.7, and 48.7 lbs per week of sodium carbonate must be removed from the copper strike tank P4-7, and cadmium plating tank P1-9, P3-13, and P5-10, respectively. The calculations seem to indicate, however, that the drag-out rates have been underestimated for cadmium plating operation. The calculated value, therefore, should be considered as an upper limit of the amount of carbonates that must be removed from the cyanide-containing cadmium plating tanks.

To remove the sodium carbonate from the copper and cadmium plating tanks, a method developed by the U.S. Army can be used (Pearlstein and Evans 1982). This method involves the immersion of a steel container holding a mixture of water and dry ice into the plating tank. The mixture will cool the adjacent plating solution and precipitate out the sodium carbonate crystals onto the surface of the container.

For the removal of carbonates from 1 copper strike tank and 3 cadmium plating baths, it will be necessary to perform the precipitating operation for each tank once a week. Based on data obtained from a test study performed by the inventors of the method, a 0.50 x 0.25 x 4.5 ft container can precipitate approximately 21 lbs of sodium carbonate

in a 4-hour immersion time interval. It is estimated that two stainless steel rectangular open-ended containers of the given size containing a mixture of 80% dry ice (by volume) must be partially immersed into each plating tank for approximately 4 to 5 hours once a week to remove carbonates buildup. The containers must be subsequently removed and adequately drained. The precipitates can then be scraped off the container and disposed of as hazardous wastes. The costs associated with the sodium carbonate removal operations are given in Table 4-5.

Since the implementation of two of the selected options, namely the use of drain boards with assumed 90% drag-out reduction and the removal of impurities must occur simultaneously to insure proper plating quality, the combined effects of these selected waste minimization options was analyzed and the results presented in Table 4-6.

The negative sign in the pay-back period presented in Table 4-6 indicates that the monthly cost for operation outweighs the savings resulting from the implementation of the two selected waste reduction options. The basic drawback of the proposed scheme is that removal of carbonate by the freeze-out method proves to be too costly. As a result, an alternate approach is needed whereby drag-out is minimized, but not at the expense of adding a costly carbonate removal system. Such an approach is given below.

For copper plating tank P4-7, mass balance calculations reveal that, based on the steady-state assumption and the highly penalizing assumption of complete carbon dioxide absorption from the air used in sparging, the current drag-out rate results in a carbonate concentration of 16.8 oz/gal in solution. The maximum limit, however, is 20 oz/gal, beyond which the plating quality becomes unacceptable. Therefore, the current drag-out rate can be reduced by a minimum of 20% and still provide the purging rate resulting in acceptable, although high, carbonate concentration. This means that additional means of carbonate removal will not be required unless drag-out rate is reduced by more than 20% of the current value. In summary, it is recommended that a drain board be installed and tested with the copper plating tank #P4-7. Carbonate level, drag-out rate, and plate quality must be monitored and if the plating quality proves satisfactory, drain boards can then be installed in the remaining tanks.

TABLE 4-5 COST DATA ASSOCIATED WITH IMPURITY REMOVAL

EQUIPMENT COSTS	
Steel Containers (2), delivered cost including sales tax (a)	$ 213
OPERATING COST, MONTHLY	
Dry Ice (b)	$ 748
Labor	900
Disposal of Waste Carbonates	77
Filter Cartridge Replacement Cost	95
TOTAL MONTHLY OPERATING COST (c)	$1,820

(a) Based on 0.50 ft x 0.25 ft x 4.5 ft steel containers.

(b) The amount of dry ice requirement was estimated based on the calculated rate of formation of carbonate in the plating baths and on the carbonate removal data given in the U.S. Army Patent No. 4,365,481 (Pearlstein and Evans 1982).

(c) Assume 90% reduction in drag-out.

TABLE 4-6 ECONOMIC ANALYSIS OF COMBINING THE USE OF DRAIN BOARDS WITH IMPURITY REMOVAL

INSTALLED COSTS	
Drain Boards - Total Installed Cost	$ 890
Impurity Removal - Total Installed Cost	213
Total Installed Cost	$1,103
INCREMENTAL SAVINGS, MONTHLY	
Drain Board - Total Savings	$ 784
Impurity Removal - Total Operating Cost	-1,820
Savings	- $1,036
PAYBACK PERIOD, MONTHS (a)	- 1.1

(a) Payback period equals total installed cost divided by savings. Depreciation, taxes and fees were not included in the calculation of payback period.

4.8.2 Drag-Out Reduction Using Drain Boards and Extension of Bath Life through Conversion to Mechanical Agitation

Elimination of air spraging in cyanide baths will greatly reduce the carbonate build-up rate, thus allowing for considerable reductions of drag-out while still providing adequate impurity purging rate. It is estimated that by using solution circulation instead of air agitation, the effective mass transfer area for CO_2 absorption can be reduced approximately by a factor of 1000. It is expected that under this condition, even with the reduced drag-out rate resulting from the use of drain boards, the carbonates formed in the plating tank can be adequately purged without requiring additional carbonate removal or periodic solution replacement. The economics of converting to mechanically agitated cyanide tanks through solution circulation is presented in Table 4-7.

For the economic analysis, it is assumed that a solution circulation system will be provided for each of the 3 cadmium plating tanks and for the copper plating tank. The pumps were sized based on the assumption of a turnover rate of 3 tank volumes per hour for each tank of less than 1000 gal and 1 tank volume per hour for the 1400 gal cadmium plating tank (Crispino 1984). To provide for adequate agitation, plating solution will be discharged through a submerged 2-ring jet nozzle manifold.

4.8.3 Drag-Out Recovery Using Still Rinsing

Still rinsing can be used to recover some of the drag-out from the plating/stripping tanks. A still tank is placed between the plating tank and the normal rinse tank. Since there is no continuous flow of rinse water into and out of the still tank, the concentration of bath constituents will build up over time, and the still rinse water can be used as make-up to the plating/stripping baths. Make-up water (deionized) can be added to the still tank periodically to provide adequate immersion of the workpiece. This can be done using a level controller.

Still rinsing can be very effective in recovering drag-out in high-temperature plating operations in which the surface evaporation rates are high (Durney 1984, Cushnie 1985). For room-temperature operations such as those observed in the present plating shop, however, the effectiveness of still rinsing as means of drag-out recovery is much lower. It is estimated that for the sizes of the present plating tanks, which are

TABLE 4-7 ECONOMIC ANALYSIS OF COMBINING THE USE OF DRAIN BOARDS WITH CONVERSION TO MECHANICAL AGITATION

INSTALLED COSTS	
Drain Boards - Total Installed Cost	$ 890
4 Pumps (a)	3,500
4 Jet Manifolds (b)	800
4 Pressure Indicators	240
Installation including labor and supplies	1600
Total Installed Cost	$7,030
INCREMENTAL SAVINGS, MONTHLY	
Drain Board - Total Savings	$ 784
Savings	$ 784
PAYBACK PERIOD, MONTHS (c)	9.0

(a) Magnetic-drive centrifugal pump, 3/4 HP, 53 gpm maximum flow rate.
(b) Based on pre-assembled 2-ring, flat-shape nozzle spray system which can be fitted to the existing plating tanks.
(c) Payback period equals total installed cost divided by savings. Depreciations, taxes and fees were not included in this calculation of payback period.

normally operated at an air sparge rate of 25 cu ft/min, the evaporation from the aerated plating baths is much less than 1 gal/hr. Based on material balance considerations, up to 40% reduction in solution drag-out is achievable once the concentration in the still rinse tank is built up to 50% of the level in the plating bath. Additional flow or spray rinse would be required following the still rinse to avoid drag-in into the subsequent bath.

The following analysis (Table 4-8) was performed to determine the economic feasibility of adding a still rinse tank after each cyanide-containing plating/stripping tanks. Due to space limitations at the plating shop, it is assumed that still rinse tanks can be added to a particularly plating sequence only when empty tanks are available. Therefore, the cost of tanks are excluded in the economic feasibility analysis. Since the drag-out rates as well as the operating costs associated with the plating operations are different for copper, cadmium, and silver, separate calculations were performed for each type of metal. This analysis also assumed that a 40 percent reduction in drag-out would not require impurity removal.

4.8.4 Wastewater Reduction Using Spray Rinsing

The use of spray nozzles on rinse tanks has been commercially proven to reduce the amount of waste rinse water generated from rack plating operation by as much as 50%. Spray rinsing or fog rinsing applied directly over a heated plating tank can also substantially reduce the solution drag-out rate. This method, however, is generally only aplicable to plating operations with very high surface evaporation rates. Therefore, it is recommended that only the rinse tanks associated with rack plating be equipped with spray systems to reduce water consumption.

In general, it will be necessary to install one spray nozzle ring for every foot of the tank's depth to provide adequate rinsing of the workpiece. Therefore, for the existing 6'-9" rinse tanks, it will be necessary to install a spray system composed of at least 5 rings per tank. The spray unit can be assembled by the manufacturer, and the whole system can be readily fitted to the existing tank. Additional costs in this case will include the cost of piping, flow control valve, and installation costs. Cost savings will be realized by lessened water requirements, by lower treatment cost (it is anticipated that calcium and magnesium present in the tap water used for rinsing will be

TABLE 4-8 ECONOMIC ANALYSIS OF DRAG-OUT RECOVERY USING STILL RINSING

	Copper Plating (1 tank)	Cadmium Plating (3 tanks)	Silver Plating/ Stripping (5 tanks)
INSTALLED COSTS			
Float Valves, delivered cost including sales tax	$160	$ 480	$ 800
Installation including labor, cleaning, and supplies	400	1,200	2,000
Total Installed Cost	$560	$1,680	$2,800
INCREMENTAL SAVINGS, MONTHLY			
Make-up Materials, Treatment, and Disposal Costs (a)	$202	$ 58	$ 89
PAYBACK PERIOD, MONTHS (b)	2.8	2.4 years	2.6 years

(a) Assumed 40% reduction in drag-out. Savings were calculated based on the same assumptions given in Table 4-4 Note (b).

(b) Payback period equals total installed cost divided by savings. Depreciation, taxes and fees were not included in the calculation of payback period.

precipitated together with heavy metals), and by resulting lower treatment sludge disposal costs.

At this point, the economic analysis included only savings due to water cost. Additional savings can be achieved in the future--when a cyanide treatment unit is constructed to separately treat the cyanide-containing wastewater due the reduction in the unit's capital cost resulting from reduced size requirements due to a much lower flow rate. The economic analysis associated with the conversion of the 9 existing rinse tanks to spray rinsing is given in Table 4-9.

4.8.5 Substitution of Non-Cyanide Cadmium Plating Solutions

Non-cyanide plating solutions have been used commercially for cadmium plating of a wide variety of parts. These solutions, however, may not provide adequate plating quality for compliance with military specifications. Therefore, it is recommended that a compatibility study should be done before the solutions given in Table 4-10 can be used as replacement for cyanide-containing plating baths.

4.9 Summary and Discussion

A preliminary economic feasibility study has been independently performed for 5 waste minimization options selected from among 31 options initially considered. These options include reduction of drag-out using drain boards, recovery of drag-out using still rinsing, extension of bath life through impurity removal, extension of bath life through conversion to mechanical agitation, and reduction of water usage using spray rinsing. Table 4-11 summarizes the results obtained from the economic analyses associated with these options.

5. AUDIT REPORT FOR FACILITY C-2

5.1 Facility Description

Facility C-2 is located in Southern California. Their main business is refinishing decorative items. The principal metals plated at this facility are nickel, brass, silver, and gold.

TABLE 4-9 ECONOMIC ANALYSIS OF WASTEWATER REDUCTION USING SPRAY RINSING

INSTALLED COSTS	
Spray Units (9), delivered cost including sales tax (a)	$9,425
Foot-activated Valves (9), delivered cost including sales tax	460
Installation including labor and pipings	1,800
Total Installed Costs	$11,685
INCREMENTAL SAVINGS, MONTHLY	
Water Cost (b)	$ 440
PAYBACK PERIOD, YEARS (c)	2.2

(a) Based on pre-assembled 5-ring, cone-shape nozzle spray systems which can be fitted to the existing flow-rinse tanks.

(b) Assumed 50% reduction in rinse water usage.

(c) Payback period equals total installed cost divided by savings. Depreciation, taxes and fees were not included in the calculation of payback period.

TABLE 4-10 NON-CYANIDE PLATING SOLUTIONS

GENERALIZED CADMIUM FLUOBORATE PLATING BATH

Constituent	Concentration (oz/gal)	Material Cost ($/lb)
Ammonium fluoborate	8.0	2.20
Boric acid	3.6	0.83
Cadmium	12.6	-
Cadmium fluoborate	32.2	2.61

Note: Fluoborate bath requires a current density of 30 to 60 A/sq ft and an operating temperature of 70 to 100 °F.
Source: Metal Handbook (Mills et al. 1983)

PROPRIETARY CADMIUM FLUOBORATE PLATING BATH

Constituent	Concentration (oz/gal)	Material Cost ($/lb)
Cadmium fluoborate	32 - 40	2.61
Ammonium fluoborate	11 - 13	2.20
Grain refiner	0.5 - 1.0% vol	22.25 (gal)

Note: This plating bath requires a current density of 10 to 70 A/sq ft, and an operating temperature of 65 to 85 °F. The solution pH should be kept at 2.8 to 3.4. The pH can be lowered by adding fluoboric acid ($1.04/lb) or raised by adding ammonium hydroxide ($0.15/lb). In addition, mechanical agitation of the plating bath is required.
Source: Millhorn Chemical & Supply Company, Maywood, Calif., personal communication. 1986.

ACID SULFATE CADMIUM PLATING BATH[13]

Constituent	Concentration (oz/gal)	Material Cost ($/lb)
Cadmium oxide	1.0 - 1.5	4.10
Sulfuric acid	4.5 - 5.0% vol	0.20

Note: Acid sulfate solution requires a current density of 10 to 60 A/sq ft and an operating temperature of 60 to 90 °F.
Source: Metal Handbook (Mills et al. 1983).

TABLE 4-11 SUMMARY OF ECONOMIC FEASIBILITY STUDY FOR FACILITY C-1A/B

Control Category	Waste Reduction Method	Waste Reduction (%)	Capital Cost ($)	Monthly Cost ($/month)	Monthly Savings ($/month)	Pay-back Period (month)
1. Drag-out Minimization	Use of drain boards	90	890	-	784	1.1
	Use of drain boards/ impurity removal	90	1103	1820	784	-
	Use of drain boards/ mechanical agitation	90	7030	-	784	9.0
	Still rinsing					
	- Copper	40	560	-	202	2.8
	- Cadmium	40	1680	-	58	2.4 yrs
	- Silver	40	2800	-	89	2.6 yrs
2. Bath Life Extension	Impurity removal	-	213	1820	-	-
	Mechanical agitation	-	6140	-	-	-
3. Rinse Water Minimization	Spray rinsing	50	11685	-	440	2.2 yrs

5.2 Equipment Layout Description

All plating, cleaning, and rinse tanks are located in one room at the plating shop, while an adjacent room houses all equipment used for buffing and polishing purposes (see Figure 5-1). The area north of the buffing room is used for drying and storage purposes. Finished goods, as well as raw goods, are stored in the front of the building. The gate at the back of the building is used as a service entrance. The area behind the facility is used for parking.

Thirty tanks are used in cleaning and electroplating operations, the contents of which are listed in Table 5-1. The layout of these tanks is shown in Figure 5-1. The configuration of a typical plating unit includes a plating bath, followed by one or two still tanks and a continuous rinse tank. Except for nickel plating, all plating/stripping solutions presently used at the facility are cyanide-based.

The waste streams generated at the facility include wastewater from electroplating operations and sanitary waste. The electroplating wastewater is collected in a sump (a two-stage clarifier, Figure 5-2) before final disposal. The sanitary waste stream goes directly into the municipal sewer system.

5.3 Process Description

Items brought in for refinishing must be cleaned, electroplated, and polished. The basic unit operations include paint stripping, cleaning, electroplating, drying, and polishing.

In silver plating, the old plating is stripped off by dipping the part into a sodium cyanide solution with the system run in reverse current, followed by an acid wash in a 50% muriatic acid solution. The part is polished to a bright finish. The polished item is then caustic cleaned to take the dirt off, rinsed with 5 percent sulfuric acid solution to neutralize the caustic solution remaining on the part, and water rinsed before being electroplated.

After the part is immersed in the plating tank for the required time interval, the item is rinsed in a still rinse tank, followed by a continuous water rinse. Tap water is used for both the still and the continuous rinsing steps. The contents of the still rinse tank

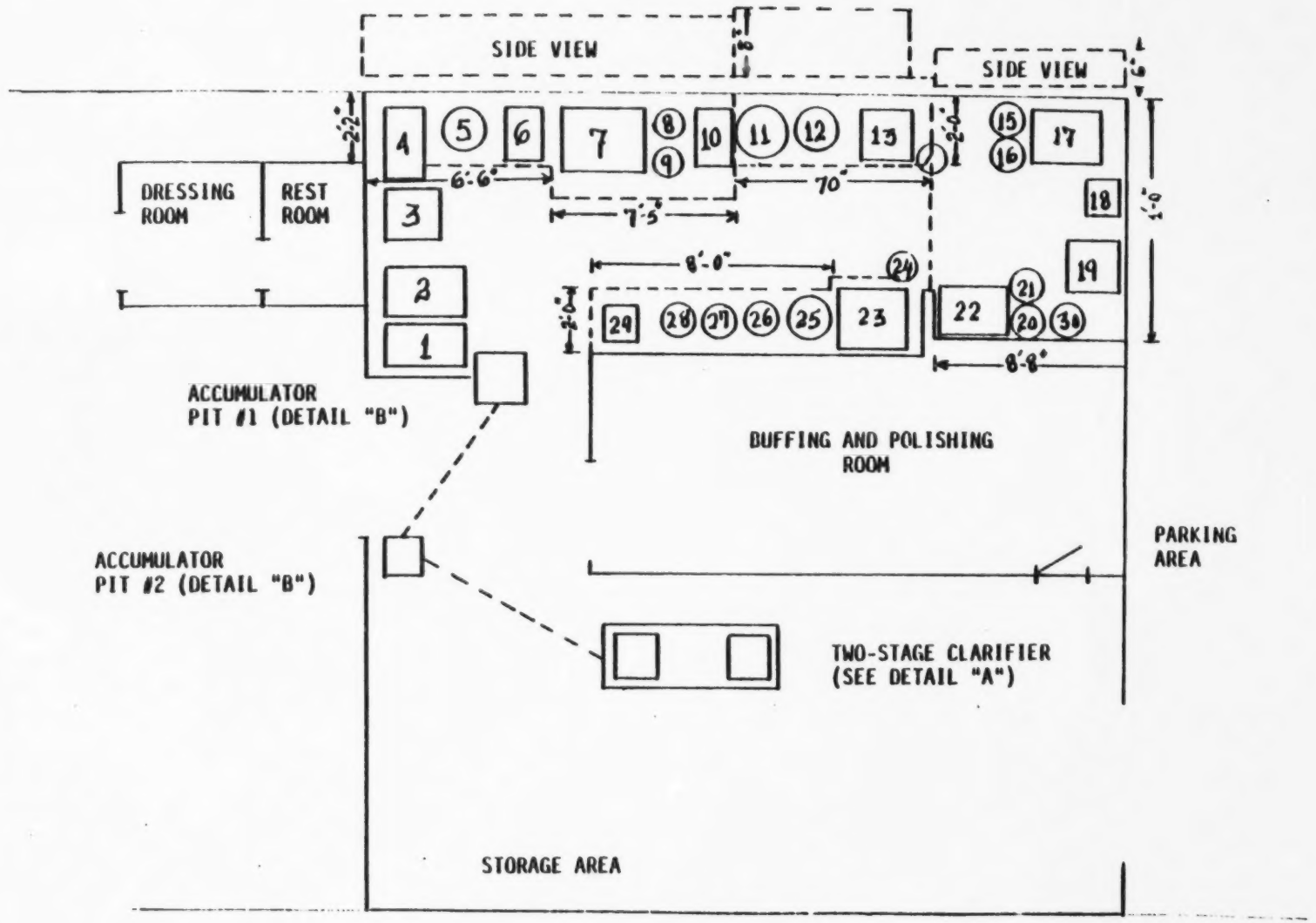
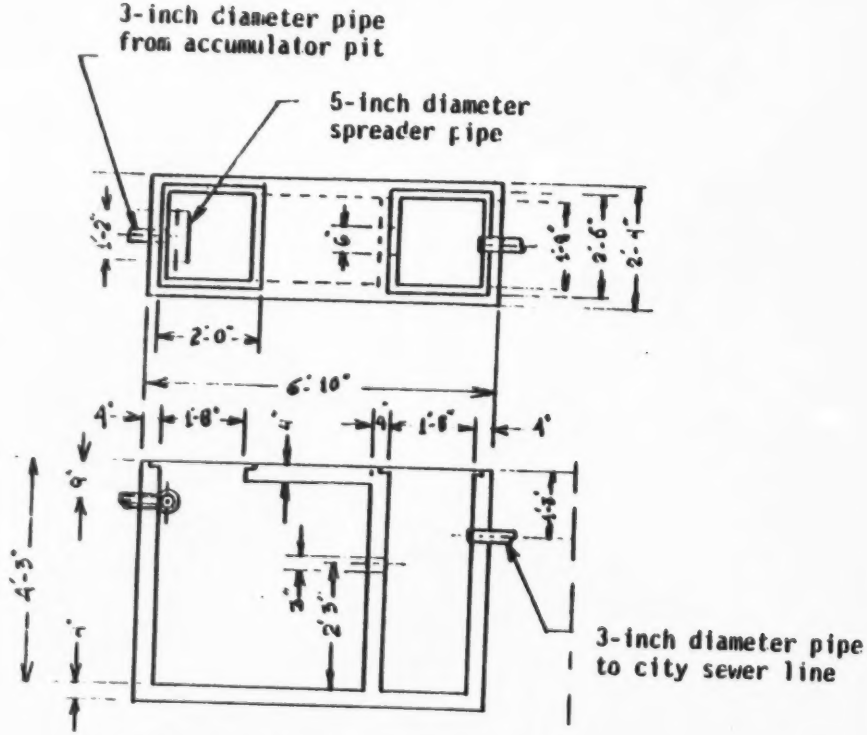


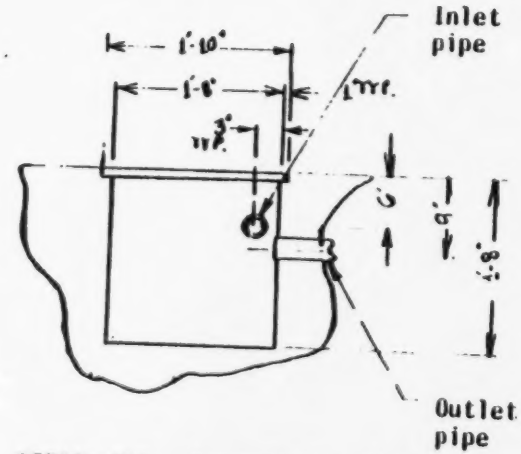
FIGURE 5-1 LAYOUT OF FACILITY C-2

TABLE 5-1 DESCRIPTION AND DIMENSION OF WORK TANKS AT FACILITY C-2

Tank	Tank Dimensions			Capacity	Tank	Solution Temperature
	Length, ft.	Width, ft.	Depth, ft.	gallons	Description	°F/Remarks
1	3.0	2.0	2.0	90	Water rinse	
2	3.0	2.0	3.0	130	Cleaner	150
3	2.0	2.0	3.0	90	Cleaner	150
4	2.5	1.5	2.58	70	Water rinse	
5	55-gallon drum, 3/4 full			41	Sulfuric dip	
6	2.0	1.67	2.0	50	Water rinse	
7	3.33	2.5	2.5	156	Copper cyanide	125
8	55-gallon drum			45	Water dip	For copper
9	55-gallon drum			45	Water dip	For copper
10	1.67	2.42	2.5	75	Hot water rinse	150
11	45-gallon drum			45		
12	55-gallon drum			40	Water rinse	
13	55-gallon drum			41	Nickel strip	
14	55-gallon drum			45	Water dip	For nickel
15	55-gallon drum			45	Water dip	For silver, alkaline
16	55-gallon drum			45	Water dip	For silver, alkaline
17	3.5	2.5	2.5	160	Silver plate	
18	1.33	1.0	2.0	15	Gold plate	
19	2.0	1.75	2.5	60	Silver strip	
20	55-gallon drum			45	Water dip	For brass
21	55-gallon drum			45	Water dip	For brass
22	3.67	2.5	2.5	172	Brass Plate	145
23	3.25	2.5	2.33	142	Nickel Plate	130
24	55-gallon drum			45	Water Dip	For nickel
25	55-gallon drum				Stainless steel strike	
26	55-gallon drum, 1/2 full			28	Chromic acid	Bright dip
27	55-gallon drum			45	Chromic acid	Water dip
28	55-gallon drum			45	Chromic acid	Water dip
29	1.75	1.5	1.5	30	Muriatic acid	
30	15-gallon drum			15	Black antique	For brass



DETAIL "A". Two-Stage Clarifier
1/2" = 1'-0"



DETAIL "B". Accumulator pits 1 and 2
1" = 1'-0"

FIGURE 5-2 DETAILS OF THE CLARIFIER AND THE ACCUMULATOR PITS 1 AND 2

are used as make-up for the plating baths. In places where two still rinse tanks are used, water from the second tank is used to replenish the first still rinse tank. Overflow from the continuous rinse tank is discharged as wastewater. The part is polished following plating operation.

Gold plating generally does not require stripping. After the initial cleaning operation, the parts are electroplated directly. Nickel and brass plating are also done in a similar fashion. Vapor degreasing using 1,1,1-Trichloroethane is often performed on brass and nickel plated items to remove oil and grease. In some cases, items are nickel plated first before gold, silver, or brass plating is done.

For electroplating operations, the cyanide solutions must be kept at an optimum concentration of the constituents. The solutions are analyzed twice a month by an outside laboratory. A representative sample from a tank is obtained by dipping a tube to the bottom of the plating tank. The sample is analyzed and recommendations for make-up are made based on the test results. Table 5-2 shows a typical analysis for brass and nickel electroplating solutions, respectively. This table also shows the optimum concentrations for each constituent in the baths, as well as the recommended make-up and/or dilution requirements.

All plating operations performed at the facility are performed manually. The facility operates one shift per day and employs eight operators.

5.4 Waste Stream Description

Cyanide waste is generated from silver stripping; from silver, gold, brass, and copper electroplating; and from associated rinsing operations. The principal waste streams are wastewater (which includes overflows from the continuous rinse tanks and water used for floor washings), and plating tank filter waste.

Aqueous streams generated from paint stripping, from metal stripping/electroplating, and from floor washings are routed to a common sump, then to the sanitary sewer. Table 5-3 provides the results of the chemical analyses performed to characterize the wastewater.

TABLE 5-2 ANALYSIS/RECOMMENDATION FOR ELECTROPLATING SOLUTIONS

Parameters for Brass	Optimum Concentration	Analyzed (Actual) Concentration
Copper metal	.....	7.52 oz/gal
Zinc metal	0.30 oz/gal	0.80
Free sodium cyanide	6.0	3.54
Caustic soda	8.0	7.50
Copper cyanide	10.0	10.60
Zinc cyanide	0.50	1.45
Rochelle salts	2.0	3.59

Recommendations:

Sodium cyanide content is low and zinc concentration is excessive.

Add 26 lbs of sodium cyanide/170 gals

Add 5½ lbs of caustic soda/170 gals

Add 8 fl ozs of De France 24S/170 gals

Parameters for Nickel	Optimum Concentration	Analyzed (Actual) Concentration
Nickel metal	.....	16.65 oz/gal
Nickel chloride	8.0	15.66
Boric acid	6.0	6.92
pH	4.0	4.5
Nickel sulfate	40.0	57.26
A-5	2.5%	2.86%
SA-1	1.2	1.38

Recommendations:

Reduce routine additions, all concentrations exceed recommended limits.

pH is excessively high, lower to 4.0.

TABLE 5-3 CHARACTERIZATION OF THE WASTEWATER GENERATED

SAMPLING DATA:	Sampling Date:	06/13/86
	Sampling Location:	Sample Box
	Type of Sample:	Time Composite
	Reporting Period:	From: April 86 To: June 86
	Wastewater Flow Determined by:	Metered Water Supply
FLOW MEASUREMENT DATA:	Total Flow (in) Gallons:	427
	Total Flow (out) Gallons:	384
	Peak Flow (gpm):	1.6
TEST:	TEST	RESULTS
	----	-------
	Suspended Solids	1 mg/l
	pH	7.7 units
	Cyanide (T)	1.3 mg/l
	Chromium (T)	0.52 mg/l
	Copper	2.56 mg/l
	Nickel	0.81 mg/l
	Silver	0.13 mg/l
	Oil and Grease	0.13 mg/l
	Temperature	65 Degrees F
SAMPLING DATA:	Sampling Date:	08/08/86
	Sampling Location:	Clarifier Sample Box
	Type of Sample:	Time Composite
	Reporting Period:	From: July 86 To: Sept. 86
	Wastewater Flow Determined by:	Metered Water Supply
FLOW MEASUREMENT DATA:	Total Flow (in) Gallons:	322
	Total Flow (out) Gallons:	290
	Peak Flow (gpm):	1.5
TEST:	TEST	RESULTS
	----	-------
	Suspended Solids	1 mg/l
	pH	7.5 units
	Cyanide (T)	1.0 mg/l
	Chromium (T)	0.42 mg/l
	Copper	1.30 mg/l
	Nickel	0.93 mg/l
	Silver	N.D. 0.05 mg/l
	Oil and Grease	0.2 mg/l
	Temperature	70 Degrees F

In addition to sump sludge, solid waste is also generated due to the accumulation of metallic sludge inside the plating tanks, which is filtered out from the plating solution once a month using a portable dual cartridge filter. Two filter cartridges are used for each plating tank. Each filter cartridge is replaced approximately every 2 to 3 months.

5.5 Current Waste Management Profile

The contents of the sump (approximately 300-400 gallons of sludge containing dirt, stripped paint, cyanides, and heavy metals) are pumped out and disposed of as hazardous waste approximately once every 6 months. The total cost of waste collection, transportation, and disposal (per visit) is expected to increase from $2,000 to $4,000 after September 1986.

5.6 Postulated Waste Minimization Options

Although the plating of different metals requires the use of various plating solutions and operating conditions, most waste reduction options are generally applicable to all electroplating processes used in the facility i.e., brass, nickel, silver, and gold plating operations.

Waste minimization options for facility C-2 can be grouped into six distinct categories. These categories include: 1) drag-out minimization, 2) bath life extension, 3) rinse water minimization, 4) substitution of non-cyanide solutions, 5) good operating practices, and 6) plant layout alterations. Each waste minimization option is either discussed below or was discussed previously in Section 4.6 of this report (Audit Report For Facility C-1A/B). The discussion includes the rationale for proposing the option, its advantages and disadvantages, and the current level of its use in the facility. Whenever possible, a quantitative assessment is also provided.

5.6.1 Drag-Out Minimization

Six drag-out minimization techniques have been initially identified as potentially applicable for plating operations at Facility C-2. Except for the measure involving proper positioning of work piece on the plating rack, the proposed methods are not

currently in use at the electroplating facility. The six drag-out minimization techniques have been discussed earlier in Section 4.6.1 and are as follows:

- o Properly position the workpiece on the plating rack.
- o Increase the plating solution temperature.
- o Lower the concentration of plating bath constituents.
- o Reduce the speed of workpiece withdrawal from solution and allow ample drainage time.
- o Use surfactants to lower the surface tension of the solution.
- o Improved drag-out recovery.

5.6.2 Bath Life Extension

By reducing the amount of drag-out from plating or stripping solutions, overall waste generation can consequently be reduced. Reduction of drag-out, however, will lead to increased level of impurity contamination in the solutions, since these impurities are normally removed by the drag-out. If the impurity buildup is high enough, it will lead to inadequate performance, and the contaminated solutions must be discarded. The resulting waste is highly concentrated with toxic compounds and requires proper disposal or extensive treatment. The following measures can be taken to increase the longevity of the plating/stripping solutions, even at a significantly low level of drag-out.

The lifetime of a plating solution is limited by the accumulation of impurities and/or depletion of constitutents. The impurities come from five sources: racks, anodes, drag-in, water make-up, and air. The impurities buildup can be reduced by the following six techniques, four of which are partially implemented at the present facility (i.e., drag-in reduction by better rinsing, use of deionized or distilled water, removal of bath impurities, and proper rack design and maintenance):

- o Drag-in reduction by better rinsing.
- o Use of deionized or distilled make-up water.
- o Plating/stripping solution regeneration through impurity removal.
- o Proper rack design and maintenance.
- o Purer anodes.
- o Return solution to manufacturers.

5.6.3 Rinse Water Minimization

The following common measures used to improve rinsing have been discussed in Section 4.6.3. These methods have been fully or partially implemented at the host facility.

- o Multiple rinse tanks.

The use of multiple rinse tanks is one of the most commonly used waste reduction options. At facility C-2, a series operation with two tanks is used.

- o Still rinsing.

Installing a still (or "dead") rinse tank immediately after a plating bath allows for metal recovery and lowered rinse water requirements (Durney 1984, Cushnie 1985). In such a system, the workpiece is immersed in a still rinse tank following the plating bath. Since the still rinse has no inflow or outflow of water, the concentrations of the plating bath constitutents build up in it. When the concentration becomes comparable to that of the upstream bath, the contents of the still bath are used to replenish the plating bath.

- o Spray or fog rinsing.

5.6.4 Substitution of Non-Cyanide Solutions

Potential alternatives to cyanide-based solutions have been discussed in Section 4.6.4. The measures proposed for facility C-2 include:

- o Pyrophosphate copper plating solution.
- o Non-cyanide silver stripping solution.

5.6.5 Good Operating Practices (GOP)

At facility C-2, the first three out of five operating practices are currently in use. Two additional methods can be used to reduce the quantity of hazardous waste generated. The following elements of GOP should be carefully considered:

- o Operator training and closer supervision.
- o Spill and leak prevention.
- o Preventive and corrective maintenance.
- o Removal of dust from inside the electroplating room.

Because of the high operating temperatures of the plating baths, evaporation takes place and moisture condenses on cold building wall surfaces. In addition, dust from the adjacent buffing room operations, from the movement of personnel, and from material handling inside the facility, acccumulates on the moist walls and ceilings of the plating room. Upon flaking, the dust can easily fall into the plating solutions. This dust then becomes a part of the accumulated sludge or may interfere with the electroplating operation itself. It is imperative to frequently clean walls and ceiling of the plating room, or avoid the buildup by improvement in air flow patterns. Clean-up of dust should be performed by using a dry vacuum and not by hosing or washing the dust down into the sump.

- o Waste stream segregation.

Presently, cyanide waste from the rinse tanks goes into the sump, along with paint sludge from the paint stripping operation. In addition, floor washings, a non-hazardous waste, also accumulate in the common sump. Thus, merely by mixing the waste streams, the amount of hazardous waste generated is increased. Segregation of hazardous and non-hazardous streams can reduce the amount of hazardous waste that must be ultimately disposed.

5.6.6 Plant Layout Alteration.

- o Wastewater routing

Alteration of waste collection schemes by segregating hazardous and non-hazardous wastes may result in the reduction of the amount of hazardous waste generated. Presently, wastewaters from all sources including paint stripping, electroplating, and floor washings are collected into accumulator pits #1 and 2 (Figure 5-1) and then transferred to the 2-stage clarifier. To reduce the volume of hazardous waste requiring disposal, it is suggested that only wastewater from floor washing should be routed to accumulator pit #1 and piped directly to the sewage (this option may require

the installation of a new piping system), whereas wastewater from electroplating operation will be accumulated in pit #2 and then routed to the clarifier via the existing pipeline.

5.7 Screening Of Cyanide Waste Minimization Options

Table 5-4 lists the various waste minimization measures noted above for each control category. Each measure has been rated on a scale of zero (low) to ten (high) with regard to waste reduction effectiveness, extent of current use, and future application potential. After rating each measure, the current and future reduction indices are determined in accordance with the technique described in Section 3.1.7.

The current reduction index is a measure of the degree to which waste has been minimized by use of the listed methods. The future reduction index is a measure of the degree to which waste can be minimized by implementation of the listed method. Each index is computed on a scale of zero to ten, with the value of ten indicating that total elimination of the waste is possible. For each control category shown in Table 5-4, the highest future reduction index has been marked by an arrow.

5.8 Feasibility Analysis of Selected Waste Minimization Options

A set of high-ranking options was selected for additional evaluation and analysis. The following options, which have the highest future reduction index (FRI) values, were chosen as candidates more detailed analysis:

1. Reduction of drag-out using drain boards.

2. Extension of bath life through the use of deionized water.

5. Reduction of water usage using spray rinsing.

4. Waste stream segregation.

For the remaining categories, no further evaluation of the proposed options were performed, either because the method's overall waste reduction potential was low or because these methods involve changes that are operational in nature (e.g., better

TABLE 5-4 SUMMARY OF WASTE MINIMIZATION OPTIONS FOR FACILITY C-2

Control Category	Control Methodology	Waste Reduction Effectiveness	Extent of Current Use	Future Application Potential	Current Reduction Index	Future Reduction Index	
Drag-out Minimization	1. Proper positioning of parts on rack	4	2	5	1		2
	2. Increase bath temperature	2	0	1	0		0
	3. Lower bath constituents concentration	2	0	1	0		0
	4. Reduce speed of withdrawal of parts	5	0	6	0		3
	5. Use of surfactants	3	0	8	0		2
	6. Improve dragout recovery	7	0	10	0	===>	7
Bath Life Extension	1. Dragin reduction by better rinsing	5	5	7	3		2
	2. Use deionized or distilled water	6	2	8	1	===>	4
	3. Bath impurity resoval	6	5	8	3		2
	4. Proper rack design & maintenance	6	3	6	2		3
	5. Purer anodes	2	0	4	0		1
	6. Return spent solution to manufacturer	8	0	4	0		3
Rinse Water Minimization	1. Multiple rinse tanks	8	4	6	3		3
	2. Still rinsing	5	5	6	3		2
	3. Spray rinsing	8	2	8	2	===>	5
Substitution of Non-cyanide Solutions	1. Non-cyanide silver stripping solution	9	0	2	0	===>	2
	2. Pyrophosphate copper plating solution	5	0	0	0		0
Good Operating Practices	1. Operator training/ closer supervision	6	4	4	2		1
	2. Spills and leaks prevention	4	4	4	2		1
	3. Preventive/ corrective maintenance	7	4	5	3		2
	4. Removal of salts and dust	5	0	6	0		3
	5. Waste stream segregation	8	0	8	0	===>	6
Plant Layout Alteration	1. Wastewater routing	8	0	5	0	===>	4

TABLE 5-4 SUMMARY OF WASTE MINIMIZATION OPTIONS FOR FACILITY C-2

Control Category	Control Methodology	Waste Reduction Effectiveness	Extent of Current Use	Future Application Potential	Current Reduction Index		Future Reduction Index
Drag-out Minimization	1. Proper positioning of parts on rack	4	2	5	1		2
	2. Increase bath temperature	2	0	1	0		0
	3. Lower bath constituents concentration	2	0	1	0		0
	4. Reduce speed of withdrawal of parts	5	0	6	0		3
	5. Use of surfactants	3	0	8	0		2
	6. Improve dragout recovery	7	0	10	0	===>	7
Bath Life Extension	1. Dragin reduction by better rinsing	5	5	7	3		2
	2. Use deionized or distilled water	6	2	8	1	===>	4
	3. Bath impurity removal	6	5	8	3		2
	4. Proper rack design & maintenance	6	3	6	2		3
	5. Purer anodes	2	0	4	0		1
	6. Return spent solution to manufacturer	8	0	4	0		3
Rinse Water Minimization	1. Multiple rinse tanks	8	4	6	3		3
	2. Still rinsing	5	5	6	3		2
	3. Spray rinsing	8	2	8	2	===>	5
Substitution of Non-cyanide Solutions	1. Non-cyanide silver stripping solution	9	0	2	0	===>	2
	2. Pyrophosphate copper plating solution	5	0	0	0		0
Good Operating Practices	1. Operator training/ closer supervision	6	4	4	2		1
	2. Spills and leaks prevention	4	4	4	2		1
	3. Preventive/ corrective maintenance	7	4	5	3		2
	4. Removal of salts and dust	5	0	6	0		3
	5. Waste stream segregation	8	0	8	0	===>	6
Plant Layout Alteration	1. Wastewater routing	8	0	5	0	===>	4

operator training), and can be addressed directly by the facility's staff. The following sections discuss each option analysis in detail.

5.8.1 Drag-Out Reduction Using Drain Boards

A drain board made of plastic or any other non-reactive materials can be used to recover solution drag-out during drainage of workpieces. The board should be placed slightly sloped toward the plating or strip tank so that drained solution can be routed back to the bath. Once attached to the tank, the drain board can serve as a workpiece rest area to allow adequate drainage in 10 to 30 seconds. The drain boards should be cleaned periodically to prevent the accumulation of dirt and the resulting drag-in of contaminants into the subsequent plating/stripping baths.

It has been estimated that for rack plating, the amount of solution drag-out can be lowered by up to 90% if the part is well drained (Durney 1984). It is suggested that for cyanide-containing plating or stripping tanks (tanks #7, 17, 22, and 30), a plastic drain board of 2 ft x 1 ft should be placed between the tank and the adjacent still rinse tanks. In cases where there is no still rinse tank immediately following the plating tank (tanks #18 and 19), a 1 ft x 1 ft drain board can be fastened to the rim of the tank to provide a resting place for proper drainage. Assuming an average of 50% reduction in drag-out, the costs and savings associated with the use of drain boards were estimated and the results are given in Table 5-5.

The estimates for savings in make-up materials were calculated from the drag-out rate from each tank and the concentrations of the major constituents in the particular plating or stripping baths. Based on the observed amount of sodium cyanide depletion rate from the brass plating solution (Table 5-2), it is estimated that the maximum drag-out rate from brass plating operation is 1 gal/hr. Since the operating procedure is fairly similar for the plating/stripping of different types of metals, it is assumed that the drag-out rate during operation from any tank is approximately 1 gal/hr.

Based on the estimated plating frequency and the relative volumes of the plating and stripping baths, it is assumed that, on the average, brass plating, copper plating, gold plating, silver plating, and silver stripping will be performed for approximately 2, 1, 0.25, 0.50, and 0.50 hours/day, respectively. The savings in make-up materials were calculated from bath concentrations as given in Table 5-2 for brass-plating, and in

TABLE 5-5 ECONOMIC ANALYSIS OF DRAG-OUT REDUCTION USING DRAIN BOARDS

INSTALLED COSTS	
Drain Boards (b), delivered cost including sales tax (a)	$115
Installation including labor and supplies	200
Total Installed Costs	$315
INCREMENTAL SAVINGS, MONTHLY	
Make-up Materials (b)	$195
Treatment and Disposal (b)	46
Savings	$241
PAYBACK PERIOD, MONTHS (c)	1.3

(a) Based on four 2 ft by 1 ft and two 1 ft by 1 ft PVC boards.

(b) Assumed 50% reduction in drag-out. The savings were estimated based on the same assumptions given in Table 4-4 Note (b).

(c) Payback period equals total installed cost divided by savings. Depreciation, taxes and fees were not included in the calculation of payback period.

published literature for copper, gold, and silver plating and/or stripping (Mills et al. 1983, Crispino 1984). Since the volume of sludge resulting from plating operations presently requiring disposal cannot be ascertained (the major portion of the sludge in the sump is attributed to paint stripping or buffing instead of electroplating operation), the estimates for savings in treatment and disposal cost were calculated based on published data associated with the treatment and disposal of wastewater generated from a copper cyanide plating operation with a drag-out rate of 1-gal/hr in an 8-hr shift (Durney 1984).

5.8.2 Extension of Bath Life by Using Deionized Rinse Water

Drag-out provides means of purging impurities from the plating/stripping bath. Therefore, any effort to reduce drag-out must be accomplished by an effort to prevent impurities from building up to excessive levels, which could adversely affect the plating quality. One such method is to use deionized water instead of tap water for still rinse tanks, since the contents of these tanks are being used to replenish the plating/stripping baths. The use of deionized water will reduce the build-up of carbonates in the plating stripping tanks, as well as possibly reduce the amount of sludge formed due to the precipitation of calcium and magnesium in the water.

A deionizing unit with 5 gpm capacity will be adequate for the total volume of still rinse tanks of 270 gal. The costs associated with the leasing of a 2-tank deionizer are given in Table 5-6.

The regeneration cost was estimated based on the cost required to replace the tanks resin units after every 2000 gal of water is processed by the deionizer. Assuming that about 270 gallons of water is required per month, it will be necessary to regenerate the deionizing unit every 7 months.

Since the frequency of contaminated bath replacement varies greatly depending upon operating conditions, it is generally impossible to quantify the savings resulting from the implementation of a bath-life extension process. This measure is often considered as a requirement for maintaining adequate plating quality, especially when a drag-out minimization method is to be implemented. Therefore, the pay-back period for this option as it stands alone is meaningless and was not calculated. The overall economics of using deionized water, however, can be considered in conjunction with the cost of

TABLE 5-6 COST DATA ASSOCIATED WITH THE USE OF DEIONIZED RINSE WATER

EQUIPMENT COSTS	
Electric light system, delivered cost including sales tax	$ 42
Filter (5 micron), delivered cost including sales tax.	80
Installation including labor and pipings	145
Total Installed Costs	$267
OPERATING COST, MONTHLY	
Renting Cost	$ 30
Regeneration Cost	8
TOTAL MONTHLY OPERATING COST	$ 38

drag-out reduction measure discussed previously (i.e., using drain boards) since the methods are not independent. Such an analysis was performed and the results are given in Table 5-7.

Since the pay-back period was estimated to be fairly short, it is suggested that drain boards should be used, in conjuction with the use of deionized water in the still rinse tanks, to reduce the amount of waste generated at the plating shop.

5.8.3 Wastewater Reduction Using Spray Rinsing

The use of spray nozzles on rinse tanks has been commercially proven to reduce the amount of waste rinse water generated from rack plating operations by as much as 50%. Spray rinsing or fog rinsing applied directly over a heater plating/stripping tank can also substantially reduce the solution drag-out rate. Since the workpieces are presently being manually sprayed when lifted above the plating/stripping tanks to reduce drag-out, it is recommended that only the continuous rinse tanks be equipped with a spray system to reduce water consumption.

In general, it will be necessary to install one spray nozzle ring for every foot of the tank's depth to provide adequate rinsing of the workpiece. Therefore, for the existing continuous rinse tanks, it will be necessary to install a spray system composed of 2 rings per tank. The spray unit can be assembled by the manufacturer, and the whole system can be readily fitted to the existing tank. Additional costs in this case will include the cost of piping, of the flow control valve, and installation cost. Cost savings will be realized by the reduced water requirement, by lower treatment cost (it is anticipated that calcium and magnesium present in tap water used for rinsing will be precipitated together with heavy metal), and by resulting lower treatment sludge disposal cost. For this facility, the economic analysis included only savings due to water cost.

The economic analysis associated with the conversion of the 4 existing continuous rinse tanks to spray rinsing is given in Table 5-8. Since the payback period was estimated to be fairly long, the option of using spray rinsing is not economically justified based on savings in water cost alone.

TABLE 5-7 ECONOMIC ANALYSIS OF COMBINING THE USE OF DRAIN BOARDS WITH THE USE OF DEIONIZED WATER

INSTALLED COSTS	
Drain Boards - Total Installed Cost	$315
Deionizer - Total Installed Cost	267
Total Installed Cost	$582
INCREMENTAL SAVINGS, MONTHLY	
Drain Board - Total Savings	$241
Deionizer - Total Operating Cost	-38
Savings	$203
PAYBACK PERIOD, MONTHS (a)	2.9

(a) Payback period equals total installed cost divided by savings. Depreciation, taxes and fees were not included in the calculation of payback period.

TABLE 5-8 ECONOMIC ANALYSIS OF WASTEWATER REDUCTION USING SPRAY RINSING

INSTALLED COSTS	
Spray Units (4), delivered cost including sales tax (a)	$2,120
Foot-activated Valves (4), delivered cost including sales tax	205
Installation including labor and pipings	500
Total Installed Costs	$2,825
INCREMENTAL SAVINGS, MONTHLY	
Water Cost (b)	$ 29
PAYBACK PERIOD, YEARS (c)	8.1

(a) Based on pre-assembled 2-ring, cone-shape nozzle spray systems which can be fitted to the existing flow-rinse tanks.

(b) Assumed 50% reduction in rinse water usage.

(c) Payback period equals total installed cost divided by savings. Depreciation, taxes and fees were not included in the calculation of payback period.

5.8.4 Waste Stream Segregation

Based on the low drag-out level estimated for the present plating operation, the amount of sludge accumulated in the sump cannot be attributed primarily to the plating operation. It is believed that two major sources of sludge generation are paint stripping sludges, and washdown of dry wastes from polishing and buffing operations. It could not be ascertained as to which of these two sources generate the largest portion of the sludge. Nevertheless, segregation of the waste generated from the polishing and buffing operation from the plating and paint stripping waste would significantly reduce the amount of sludge accumulated in the sump, and thus lower the resulting waste disposal cost. The following sections discuss the analysis of waste segregation measures.

(1) Dry cleaning of dust and buffing waste. To prevent dust from buffing operations from entering the sump, the wash-down of floors using water hose should be performed only after the area has been thoroughly vacuumed. The resulting dry waste can be disposed of as non-hazardous waste. Assuming 10% of the sludge comes from dust and buffing, the sludge will have to be removed less frequently, and thus the disposal cost can be reduced by up to 10% (approximately $800/year).

(2) Replacing caustic paint stripping with plastic media blasting. Paint from parts can be removed by blasting the parts with plastic beads. By replacing caustic paint stripping with dry blasting, substantial savings in disposal costs can be realized due to the much lower transportation and disposal cost of stored dry waste, compared to the removal of paint sludge from the sump. The facility presently has a small blasting cabinet which is used mainly for small workpieces. The following analysis assumes that a larger cabinet would be purchased to accommodate the removal of paint from most of the workpieces.

It is assumed that 90% of the sludge in the sump comes from the paint stripping operations (approximately 720 gal paint sludge/year). Assuming the sludge solid content to be 15%, approximately 96 gallons of dry paint waste will be generated per year. To avoid excessive hauling and disposal costs, it is suggested that the paint waste be stored in-house until the total waste exceeds 275 gal (five 55-gal drums) before disposing. Based on mass balance calculations, it is estimated that the facility

would dispose of the accumulated 275 gallons of dry waste approximately every 3 years. The results of the economic analysis are given in Table 5-9.

5.9 Summary and Discussion

A preliminary economic feasibility study has been independently performed for 4 waste reduction options selected among 23 options initially considered. These options include reduction of drag-out using drain boards, extension of bath life through impurity removal, reduction of water usage using spray rinsing, and reduction of waste disposal cost by waste stream segregation. Table 5-10 summarizes the results of the economic analyses for these options.

TABLE 5-9 ECONOMIC ANALYSIS OF CONVERTING TO DRY PAINT STRIPPING

INSTALLED COSTS	
Blasting Cabinet (model PRAM-31), delivered cost including sales tax (a)	$11,075
Air Compressor (25 HP), delivered cost including sales tax	5,325
Installation including labor and supplies	1,500
Total Installed Costs	$17,900
INCREMENTAL SAVINGS, YEARLY	
Waste Disposal Cost (a)	$ 6,607
Blasting System Operating Cost (b)	- 1,957
Plastic Blasting Media Replacement Cost (c)	- 562
Savings	$ 4,088
PAYBACK PERIOD, YEARS (d)	4.4

(a) Assume 90% of the sludge (15% solid) in the sump comes from paint stripping operation and 10% of the plastic blasting media is mixed with the dry-paint waste. Taken into account the expected increase in disposal cost in the near future, it is assumed that the disposal cost will increase 3 fold when the dry paint waste is accumulated to five 55-gallon drums (3 years).

(b) Assumed operating costs include utility cost for running the air compressor 4 hrs/day and maintenance cost, which is estimated to be approximately 3% of the total capital cost.

(c) Assume plastic blasting media must be completely replaced every 3 months.

(d) Payback period equals total installed cost divided by savings. Depreciation, taxes and fees were not included in the calculation of payback period.

TABLE 5-10 SUMMARY OF ECONOMIC FEASIBILITY STUDY FOR FACILITY C-2

Description of Options	Method	Percent Waste Reduction (%)	Capital Cost ($)	Monthly Cost ($/month)	Monthly Savings ($/month)	Pay-back Period (month)
1. Drag-out Minimization	Use of drain boards	50	315	--	241	1.3
2. Extension of Bath Life*	Use of deionized water	50	582	38	241	2.9
3. Rinse water Minimization	Use of spray rinsing	50	2,825	--	29	8.1 years
4. Good Operating Practices	Use of plastic media blasting	90	17,900	2,519/yr	6,607/yr	4.4 years

*Economic analysis was performed in conjunction with the implementation of drain boards.

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